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ELEMENTS

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OF

C H E M I S T R Y.

BY

John
J. MURRAY,

LECTURER ON CHEMISTRY, MATERIA
MEDICA, AND PHARMACY.

VOLUME II.

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Circumstances having rendered it necessary that the present Volume should be published by a certain period, the following errors have passed unobserved from the hurry of the Press. These the Reader is requested to correct, as several of them affect the sense.

Page 8, line 3, before oxyd, read im-
perfect
— 19, — 18, for melting, read weld-
ing
— 53, — 16, before vinegar, read
the refuse of the
grape mixed with
— 57, — 8, for silver, read sulphur
— 64, — 5, for gas, read acid
— 86, — 2, for flashes, read flakes
— 96, — 5, for oxygen, read sulphur

Page 97, line 7, for proportion, read
preparation
— 138, — 11, erase the words coars-
er grain
— 163, — 4, for coarse, read coarse
— 16, before separated, read
easily
— 18, for thin, read thick
— 212, — 14, before may, read which
— 532, — 10, for nitric, read malic
— 545, — 3, for alkali, read alcohol

ELEMENTS
OF
CHEMISTRY.

CHAP. V.

METALS.

METALS are perhaps, strictly speaking, inflammable substances, as they are capable of combining with oxygen; and several of them, during this combination, exhibit the phenomena of combustion, or emit light and caloric. But they are distinguished from the inflammable substances hitherto considered, and from every other class of chemical agents, by certain properties,—by a greater specific gravity, and by more or

less ductility, malleability, opacity, lustre, and hardness. They are simple bodies ; in other words, have not been decomposed.

In *Gravity*, the metals are superior to every other class of substances ; the heaviest fossil, not metallic, having a specific gravity to water nearly as 4.5 to 1 ; while that of the lightest metal is as 7.3. Their *Opacity* is also much greater ; they have even been considered as absolutely opaque, as the thinnest plates into which they can be beat without their texture being injured, do not transmit light. From the conjunction of these two properties, arises another by which they are distinguished,—that of reflecting from their surface the greater part of the light that falls upon them, constituting their *lustre* or brilliancy. From their density, they are also susceptible of a fine polish. *Colour* is not a characteristic property of the metals, but it is possessed by them, and serves to distinguish them from each other.

Tenacity, or the strong cohesion of their particles, distinguishes a number of the metals, and is possessed by them in a greater degree than by other bodies. It gives rise to two properties, *Malle-*
ability

ability and *Ductility*; the former being that by which they may be beat into extremely thin plates, without their texture being injured—the other, that by which they may be drawn into fine wire. These properties, though closely allied, are not precisely the same, as they are possessed in different degrees by the different metals, some being more malleable than others, though less ductile. Those metals which possess little tenacity were termed Semi-metals:—an improper distinction, which is now discarded.

In *Hardness*, the metals are inferior to the diamond, and some earthy bodies; but they in general possess it in so great a degree, that it may be stated as one of their distinguishing properties, and the degrees of it serve as one distinction among the several metals. Art can give them a greater degree of hardness than they naturally possess, principally by raising their temperature, and reducing it suddenly. Their elasticity follows the same order as their hardness.

Fusibility belongs to all the metals, though there are great differences among them with respect to the temperatures at which they are fused.

Mercury

Mercury is always fluid at any temperature, superior to 40° below 0° of Fahrenheit, while Platina or Molybdena can scarcely be fused by the most intense heat. When melted, if the reduction of heat has been gradual, they undergo a species of crystallization; and in nature, several of them are found in regular crystalline forms. They can likewise be volatilised by heat.

The metals are better conductors both of caloric and the electric fluid, than bodies belonging to any other class.

Metals are very susceptible of combination. They unite with oxygen, carbon, sulphur, phosphorus, and with each other; and their oxyds combine with the acids, the alkalis, and the earths.

Of these combinations, that with oxygen is the most important. If a metal is heated to a certain temperature in contact with oxygen gas or atmospheric air, it loses its brilliancy, tenacity, and hardness; and is converted into a substance, generally resembling in its properties the earths. This change is accompanied with an absorption of oxygen,

oxygen, and is nothing but the oxydation of the metal. It was formerly termed Calcination, and the product a Calx;—terms for which those of metallic Oxydation and metallic Oxyd, have been substituted. It takes place at very different degrees of temperature in the different metals, and with different degrees of rapidity; in some it is accompanied with all the phenomena of combustion,—in others, there is scarcely any perceptible emission of light or caloric. It is in general more rapid in oxygen gas than in atmospheric air.

According to the theory of Stahl, metals are compounds of peculiar earths with phlogiston: in that process, therefore, by which, when heated in contact with atmospheric air, they lose their metallic appearance and properties, he supposed that the phlogiston is disengaged, and that the substance obtained is the earthy matter with which that principle was combined. But this explanation, like the general Stahlian hypothesis, was unable to explain why the presence of the air is necessary to this process, and why the weight of the metal is not diminished but increased,

Of the modern chemists, Bayen was the first, who from these facts was led to doubt of this hypothesis; and as he obtained from several metallic oxyds by heat a quantity of aerial fluid, he ascribed the weight they gained in calcination to air which they had absorbed. Lavoisier prosecuted these researches. He shewed, in particular, that it is to the absorption of oxygen that the change which the metal suffers is owing: and he proved by accurate experiments, that what the older chemists termed the calcination of a metal, cannot go on without the presence of oxygen; that this oxygen is absorbed; that the weight which the metal gains, corresponds to the weight of the quantity of oxygen which disappears, and that this oxygen may again be recovered, in some cases merely by exposing the product of the calcination to heat,—in others, by mixing it previously with another body, to which the oxygen has a stronger attraction than it has to the metal.

The different metals have different forces of attraction to oxygen, and combine with it with different degrees of facility. Some attract it at the temperature of the atmosphere, others cannot be combined with it, even when raised to the most intense

intense heat. It is singular that the combination of two metals is more easily oxydated than either of them separately.

The different metals are capable of combining with different quantities of oxygen : some absorb nearly half their weight, others not the tenth or twelfth part. Each metal too is capable of various degrees of oxydation, always, however, determinate in each ; and at each degree different properties are acquired. Changes of colour, in particular, mark the successive quantities of oxygen combined with the metal ; and it is generally from their colour, that the different oxyds of the same metal are named. In these different states of oxydation, the force by which the oxygen is retained is different. In conformity to the general law, that attraction is in the inverse ratio of saturation, it is in general strongest in the first, and weaker in the successive degrees. Some metals are capable of being so highly oxygenated, as to acquire the properties of acids.

The greater number of the metallic oxyds when exposed to a heat sufficiently intense, are fused ; and, instead of retaining the opacity of the
metals

metals, form a perfect glass. There are some of them, however, which when heated to ignition are decomposed, and part with their oxygen. Others part with only a certain portion of it, and remain in the state of oxyd. Those which have a still stronger attraction to their oxygen, may be decomposed by heating them with other inflammable bodies, particularly with these containing carbon; the carbon attracts the oxygen, forms carbonic acid, and the metal is obtained in its metallic state. This operation, in the language of chemistry, is termed Reduction.

Besides the oxydation which metals suffer by exposure to atmospheric air, or oxygen gas, they may be made to undergo a similar change, by exposing them to the action of substances already oxydated, and from which the oxygen may be transferred. They may thus be oxydated from the decomposition of nitrat of potash, or oxygenated muriat of potash, of acids, or of water.

When a metal is exposed to a red heat, with a quantity of nitrat of potash, it is rapidly oxydated, and, in general, a large quantity of light is given out; some require to be raised to a higher temperature

perature than others ; and there are three,— platina, gold, and silver,— which are not oxydated by this process at any temperature. By mere trituration with the oxygenated muriatic of potash, as has already been remarked, the metals are oxydated, with deflagration or detonation.

Those metals which have a stronger attraction to oxygen than hydrogen has, may be oxydated by decomposing water. The oxydation from this decomposition goes on even at the common temperature of the atmosphere, but very slowly ; at the temperature of ignition it is rapid, and is equally so at low temperatures, when promoted by the disposing affinity of an acid.

Metals may likewise receive oxygen from acids. The nitric and oxygenated muriatic acids part with oxygen with great facility to the greater number of them ; and the sulphuric is likewise in general partially decomposed by them, especially when the attraction of the metal to the oxygen is promoted by a high temperature. In other cases, the sulphuric acid enables the metal to attract oxygen from the water with which it may be diluted,

ted, and the muriatic acts upon them by the same operation.

When a metal has been oxydated, it acquires an attraction to the acids, and becomes capable of combining with them. Hence, when an acid is poured upon a metal, the first effect is a decomposition of part of the acid or of the water present, so as to oxydate the metal; and this oxyd combines with the remaining acid, and forms a perfect solution. Or if the metal has been previously oxydated, the union of the oxyd with the acid takes place with facility. No metal is capable of directly combining with an acid; it must always be first oxydated. Although it owes, however, its capability of combining with the acids to oxygen, a certain degree of oxygenation is necessary for this purpose. In many cases, if a metal is saturated with oxygen, it is insoluble in the very acid in which, when less highly oxydated, it is easily soluble. Hence metallic solutions, when exposed to the atmosphere, frequently become turbid, and deposit a quantity of oxyd, from the metal having attracted more oxygen. Hence also, when a metallic solution is heated, a similar deposition takes place, from the metal being

being able by the heat to decompose a fresh portion of the acid, and acquire more oxygen. And lastly, from the same cause, several metallic oxyds are insoluble in sulphuric, nitric, or oxygenated muriatic acid; but dissolve in the sulphureous, nitrous, or muriatic,—these latter abstracting a portion of their oxygen, and thus rendering them soluble.

The combinations of the metallic oxyds with the acids are of a saline nature, possessing certain general properties, similar to those of the compounds formed by the acids with the alkalis or earths. When the acid is fully saturated with the metallic oxyd, its acid powers are lost, the combination is in general soluble in water, and may be made to crystallize. From the analogy of these to the neutral salts, they are termed *Metallic Salts*, and the same nomenclature is used with respect to them. Those formed by the sulphuric acid, for example, are termed *Sulphats*; as *sulphat of iron*, of *copper*, &c. In strict propriety these ought to be termed *Sulphated Oxyd of iron*, &c.; and the same nomenclature should be used with respect to the others: but the other nomenclature, for its preciseness, is preferred.

Metallic

Metallic salts can be formed, in which the metal exists in different states of oxydation. It is a deficiency in the new nomenclature that these differences of composition are not accurately expressed. In general it is done from their peculiar properties; as, the green and brown sulphats of iron, the mild and the corrosive muriats of mercury.

The force of attractions of the metallic oxyds to the acids, is much inferior to that of the alkalis, or earths: hence a metallic solution is decomposed by the addition of any of these substances. The earths, potash, and soda, generally precipitate the oxyd, as it existed in the solution; ammonia frequently re-acts upon it, partially decomposes it, or combines with it and the acid, and forms a ternary compound,

A metallic solution may be frequently decomposed by the addition of another metal different from that which has been dissolved. This is owing not to the attraction exerted by the metal to the acid, but to the attraction which it exerts to the oxygen contained in the metallic oxyd that was dissolved. The latter, being deprived of its
oxygen,

oxygen, becomes insoluble, and therefore falls down in its metallic state ; the former, acquiring this oxygen, becomes capable of combining with the acid, and is therefore dissolved. Sometimes the metal precipitated is not entirely deprived of its oxygen, but only so much so as to render it insoluble. From these precipitations it is generally supposed, that the order of attractions of the different metals to oxygen may be inferred,—the acid being considered merely as the vehicle by which they are allowed to operate. It is probable, however, that the acid will modify these attractions, by its disposing affinities to the oxyds.

The different acids have very different degrees of attraction to the metallic oxyds ; and hence, if a metal is dissolved in one acid, it may frequently be decomposed by the addition of another,—the acid added exerting a stronger attraction to the oxyd, than the one does with which it was combined.

The metals do not seem to be capable of combining, either in their metallic or oxydated state, with hydrogen or azot. Some of them enter into combination with carbon, and the greater number
of

of them with sulphur. The alkaline sulphurets are likewise capable of dissolving both the metals and their oxyds; and these oxyds also combine with sulphur, and with sulphurated hydrogen. These combinations of sulphur with the metals are singular, as presenting phenomena similar to those of combustion. They take place at a temperature not much higher than that at which the sulphur melts; and at the moment of combination, light and caloric are extricated. It remains undetermined, whether these phenomena are not owing to the oxydation of the metal by the water which the sulphur may contain, its previous union with the sulphur enabling it to decompose the water with more rapidity—or whether they may not arise from the mere combination of the sulphur and metal, the light being extricated from one or both of them, and the caloric being evolved in consequence of a change of capacity.

Phosphorus combines with the metals forming metallic phosphurets, which in general retain a considerable share of the metallic splendour.—These combinations are most easily effected by exposing to heat a mixture of the metal, phosphoric acid, and charcoal,—the carbon attracting the oxygen

oxygen of the acid, and the phosphorus, when reduced, combining with the metal.

The metals are capable of combining with each other by fusion. Such compounds, in the new nomenclature, are termed Alloys. They always possess the metallic properties, but differ, often very considerably, in their specific gravity, hardness, tenacity, fusibility, &c. from the simple metals of which they consist. In these combinations, very different forces of attraction are exerted by the different metals: some cannot be combined, and others, when combined, can with difficulty be separated.

The metals exert no attraction to the earths: the metallic oxyds combine with them, and form coloured glasses.

The metals are found in different states in nature. When in their metallic state, or when one metal is combined with a portion of another, they are said to be Native; when combined with other substances, they are Mineralised, or in the state of Ore. They are thus mineralised by oxygen, sulphur, oxyd of arsenic, and the different acids,---
particularly

particularly the carbonic, muriatic, sulphuric, and phosphoric.

In order to render the descriptions of the metals and their ores more precise, the most striking characters by which they are discriminated have been rendered more appropriate, by expressing their degrees in numbers, than they could be by any other mode of expression. The following are those assigned by Kirwan, and which are referred to in the following descriptions.

Of Lustre, there are 5 degrees: 4. denotes the strongest, such as that of diamond and polished metals; 3 denotes a weaker, such as that of crystals or metals not much polished; 2. denotes a still weaker, as that of silk, or still less glossy; 1. when only a few particles reflect any lustre, or when it is exceedingly weak; 0. dull, reflecting no lustre at all.

Of Transparency there are likewise 5 degrees: 4. denotes that degree which allows objects to be clearly distinguished; 3. that which suffers objects to be perceived, but not distinctly; 2. that which transmits light, but does not permit objects

to

to be discerned; 1. that which transmits light only at the edges; 0. denotes perfect opacity.

Of Hardness there are the following degrees: 3. denotes the hardness of chalk; 4. a superior hardness, but yet such as yields to the nail; 5. that which will not yield to the nail, but easily, and without grating, to the knife; 6. that which yields with more difficulty to the knife; 7. that which scarcely yields to the knife; 8. that which cannot be scraped by the knife, but does not give fire with steel; 9. that which gives a few feeble sparks with steel; 10. that which gives plentiful lively sparks.

The terms expressing the other properties of minerals, it is unnecessary to notice, as they are not expressed in this arbitrary manner. They are accurately defined by Mr. Kirwan.

The metals and their ores are generally found in the cavities or crevices of rocks, forming what are termed Veins. The metallic matter is very generally incrustated and intermingled with some earthy matter different from the rock in which the vein is situated: this is termed its Matrix. To

obtain the metal, the matrix is separated by pounding, washing, and other mechanical contrivances, or by fusion. If it is in the state of ore, and is mineralised by sulphur, oxyd of arsenic, or some of the acids, it is roasted to expel these substances; is reduced by fusing it in contact with the burning fuel,—and the metal thus obtained is purified from other metals, which may be mixed with it by various processes; as, repeated fusion, amalgamation, eliquation, &c.

The metals, which amount to 21, distinguished by peculiar properties, have been classed under several divisions, as Noble or Perfect metals, Imperfect and Semi-metals; metals oxydated by heat, and not oxydable, acidifiable, &c. These divisions are imperfect, and are entirely unnecessary. They may merely be arranged, so that those which in their general properties have the greatest resemblance may succeed each other, beginning with those that possess in the most eminent degree the peculiar metallic properties,—gravity, tenacity, and lustre.

See.

SECT. I. — — PLATINA.

THIS metal has been found only in the mines of Peru, intermixed with gold. It is found in a native state, in the form of small grains, which consist of platina alloyed with a portion of iron, and mixed with various ingredients. When freed from these, its specific gravity is equal to 1600. When purified from this intermixture, so as to be no longer magnetic, it has a specific gravity equal to 20.98, or, when hammered, to 23.66 — and is therefore the heaviest body existing in nature: its colour is white; lustre, 4. which does not tarnish on exposure to the air; it is ductile and malleable, its hardness is 7.5.

THIS metal requires a very intense heat for its fusion; it cannot indeed be melted in the most powerful furnace, but only by the fire urged by a stream of oxygen gas. It possesses the property of melting, or softening at a temperature much inferior to that necessary to fuse it, so that two
pieces

pieces of it may be joined by hammering, a property possessed only by it and iron.

Platina is not oxydated by exposure to atmospheric air or oxygen at any temperature; neither is it altered by water, or by any of the acids, the oxygenated muriatic and the nitro-muriatic excepted. These part with oxygen so easily, that the platina is oxydated; its oxyd combines with the muriatic acid, and, by evaporation, crystals of muriat of platina are obtained.

This is the only saline combination of this metal, the properties of which have been examined. It appears that the platina exists in the solution in two states of oxydation. On adding potash to it, a precipitate is formed, which is a triple compound of the alkali, acid, and platina, highly oxydated; it is sparingly soluble in water, and of a saline nature:—when more potash is added, another precipitate is thrown down, which is the imperfect oxyd of platina. Ammonia acts in a similar manner on the solution; and the muriat of ammonia likewise forms a triple compound of perfect oxyd of platina, muriatic acid, and ammonia, which, being insoluble, is precipitated. By
this

this property of affording a precipitate on the addition of muriat of ammonia to its solution, platina is distinguished from every other metal. Soda and lime precipitate only the imperfect oxyd. This oxyd is of a yellow colour, is tasteless, and insoluble in water; it is reducible by heat, and is soluble in the greater number of the acids.

Platina does not combine with carbon or with sulphur. It unites with phosphorus — the compound retains the metallic lustre; is brittle, hard, and fusible. It is decomposed by heat; and this decomposition has been employed as a method of obtaining the platina free from iron or any other metal.

With the other metals, or at least with the greater part of them, platina unites by fusion. Of these alloys, that with copper is the most valuable, as it is susceptible of a fine polish, and does not tarnish on exposure to the air. It does not amalgamate with mercury.

Platina is valued for its great hardness and infusibility, and for its not being tarnished on exposure

exposure to the air. It is principally used in the construction of chemical vessels.

Sect. II. — — GOLD.

THIS is esteemed the most valuable of the metals, on account of its great gravity, ductility, malleability, and lustre. It is found native ; never, perhaps, perfectly pure, but combined with other metals in a disseminated, compact, or crystallized form, or in grains. It has likewise been supposed, that it is mineralised by sulphur and arsenic, and by antimony : but mineralogists are in general agreed, that in ores which have been supposed to be of this nature, the gold is not combined with any mineraliser, but is only alloyed with some other metals, principally with silver, copper, iron, and tellurium, these alloys being frequently mixed with other ingredients. The principal ores of this kind are the *aurum graphicum*, and the grey and yellow gold ores of Nagaya. These all contain the newly-discovered metal tellurium.

Native

Native gold, when loosely interspersed in any matrix, or mixed with sand, may be in a great measure freed from the foreign substances with which it is mixed, by placing it in a stream of water, which carries them off. The metallic residuum is triturated with 1-10th of its weight of mercury, until all the particles of gold are dissolved: the mercury is distilled off, and the gold remains. When it is contained in other ores, the ore is roasted, to expel the sulphur and arsenic; and the gold is collected by washing and fusing the remaining ore with lead, with which the gold combines, and from which it is freed by the process termed Cupellation. This process is even necessary to obtain gold pure, which has been obtained by amalgamation with mercury: it consists in combining the gold with a quantity of lead, and exposing the alloy to a melting heat in a vessel termed a Cupel, formed of bone ashes, and extremely porous. The lead is oxydated, and the oxyd vitrified; it sinks into the cupel, and leaves the gold nearly pure. It can contain only silver, which is separated by the solvent power of the nitric acid, forming the operation termed Quartation, or Parting.

Gold,

Gold when pure is of a rich yellow colour; its lustre, which is equal to 4. is not impaired by exposure to air or moisture; its specific gravity is from 19.30 to 19.64; its hardness 6; its ductility is so considerable, that a wire of $\frac{1}{10}$ th of an inch in diameter supports, without breaking, a weight of 500 lbs. In malleability it is superior to every other metal; one grain of it may be made to cover a space of 36 square inches, and it can be extended 12 times more than this.

Gold melts at 32 of Wedgewood's thermometer, and by an intense heat, as that of a mirror, is volatilised unchanged. It is incapable of oxydation from atmospheric air or oxygen gas, at any temperature, at least any which a furnace can yield; neither does it suffer this change from nitrat of potash.

Its attraction to oxygen is so weak, that it likewise is incapable of decomposing any of the acids, the oxygenated muriatic acid excepted. This, either pure or as it exists in the nitro-muriatic, affords it oxygen; and the solution of the metal proceeds in it with considerable rapidity. The saturated solution is of a rich yellow colour, and
is

is highly corrosive. By evaporation it affords yellow deliquescent crystals of muriat of gold.

The fixed alkalis, lime, and magnesia, decompose muriat of gold, by attracting its acid; an oxyd is thrown down, of a yellow colour, which contains very little oxygen, and which parts with it when heated to ignition. This oxyd is soluble in the nitric, sulphuric, and several other acids.

Ammonia likewise decomposes muriat of gold, and throws down a precipitate, which is not, however, a pure oxyd of the metal. It is distinguished by the property of fulminating with the greatest violence from friction, or from being gently heated, and has hence been termed Fulminating gold. Berthollet has shewn, that it is a compound of ammonia and oxyd of gold. When heated, the oxygen of the oxyd combines with the hydrogen of the ammonia, and forms aqueous vapour—the azotic gas is disengaged; and to the rapid extrication of these heated gases, the violent detonation is owing.

Muriat of gold is decomposed by the greater number of the metals; these having a stronger attraction to oxygen than gold has. Copper and iron throw it down in its pure metallic state; and the other metals precipitate it in the state of a purple oxyd, containing a small proportion of oxygen. The precipitate by tin, termed the Purple Powder of Cassius, is used in enamelling and colouring glass. It is also precipitated in its metallic form by sulphat of iron. The volatile oils or the ethers, added to the solution of muriat of gold, attract the oxygen of the oxyd, and the metal is diffused through the liquor in particles of great tenuity, communicating to it a rich yellow colour: such mixtures have been termed Potable Gold. Lastly, the muriat of gold is decomposed by the alkaline sulphurets; the alkali uniting with the acid, and the sulphur with the oxyd of gold.

This metal, in its metallic state, is incapable of uniting with sulphur, but it combines with sulphuret of potash. This compound is obtained by fusing equal parts of sulphur and potash with 1-4th part of gold; it is soluble in water, and is decomposed by the acids. It is also capable of
combining

combining with phosphorus, forming a white, brittle, and fusible compound,

Gold forms alloys with the greater number of the metals. The compound with platina retains considerable ductility and specific gravity, but is deprived of the golden colour. With silver, it forms an alloy of considerable ductility, of a pale yellow or green colour. Copper heightens its colour, and, without much impairing its ductility, renders it harder; and hence an alloy of this kind is generally used when gold is fabricated into plate or coin. Tin greatly impairs its tenacity.

Gilding is an art by which gold in thin leaves is applied to the surface of other metals, or of wood. On the latter, it is fixed by an adhesive glue; on the former, by various means, but most completely by an amalgam of it with mercury, the mercury being afterwards driven off by heat.

SECT. III. — — SILVER.

THIS resembles the preceding metals in not being oxydated by heat; it is next to gold in malleability and ductility; its lustre is also pearly the same, but is tarnished on exposure to the air, not from oxydation, but from the operation of animal effluvia, probably sulphurated hydrogen. Its colour is white. Specific gravity, 10.55; hardness, 6.5.

Silver is found both native and mineralised. Native silver is always alloyed with other metals; it occurs crystallized, compact, and interspersed. It is mineralised by oxygen, sulphur, oxyd of arsenic and of antimony, muriatic and sulphuric acids, forming the vitreous and red silver ores, the arsenical silver, the horn silver, &c. There are many ores of other metals, as the sulphuret of lead, the grey copper ore, and others, which contain silver in smaller quantity, yet often so much of it as to render it an object of importance to extract it.

Silver

SILVER.

29

Silver, when native, is separated from the ore by pounding, washing, and amalgamation with mercury; when mineralised, it is roasted, and fused with charcoal and iron: the silver obtained is freed, by cupellation, from the metals with which it is combined.

Silver is fused at 28 degrees of Wedgewood's scale, and may be volatilised by an intense heat. It can hardly be oxydated at any temperature by atmospheric air: the electric discharge transmitted over silver leaf is capable, however, of oxydating and vitrifying it.

Several of the acids afford it oxygen, and dissolve it: sulphuric acid does so when assisted with a boiling heat: a sulphat of silver is formed, very sparingly soluble in cold water, but which can be dissolved in boiling water, so that the solution, on cooling, affords minute crystals. The nitric acid, even in the cold, oxydates, and dissolves the metal with rapidity, nitrous gas being disengaged: the solution is colourless, and, when saturated, affords white foliated crystals, very soluble in water. These are fused by heat, and form the pharmaceutical preparation termed Lu-

nar Caustic. The muriatic acid does not act upon silver in its metallic state, but it exerts a strong attraction to its oxyds, and attracts it when added to the nitrat of silver. The muriat of silver is nearly insoluble in water: it is fused by a moderate heat into a perfect glass, partly flexible, and even malleable, and which has hence been named *Luna cornea*. This is decomposed by heat, and the purest silver is obtained from this decomposition, a small quantity of potash being added to facilitate it. These salts are blackened by exposure to light, from a partial reduction of the oxyd of silver.

As the alkalis and earths have a stronger attraction to the acids than the oxyd of silver has, they decompose the salts that it forms. Potash, soda, and lime, throw down an oxyd of a brown colour, which is reducible to the metallic state by heat alone. Ammonia throws down a black precipitate, apparently differing from the former in containing less oxygen. It possesses no fulminating property, like the precipitate by ammonia from gold. A fulminating preparation, however, much more powerful even than the *aurum fulminans*, may be obtained by a particular process. By adding lime water to the nitrous solution of sil-

ver, an oxyd is precipitated, which is dried by exposure to the air, and then stirred in the watery solution of ammonia: it is thus converted partly into a black powder, and partly into a crystalline matter, either of which detonates with the utmost violence on the slightest friction, so that a minute quantity only can be made at a time with safety, and this cannot even be removed from the vessel in which it is prepared. The detonation is no doubt to be ascribed to the hydrogen of the ammonia suddenly combining with the oxygen of the metallic oxyd, and forming aqueous vapour, which is disengaged along with the azotic gas; the elasticity of both being augmented by the caloric likewise let loose. No explanation has been given, why its force is so much greater than that of the fulminating gold; but it is probably owing to the silver in the state of oxyd containing a larger proportion of oxygen than the gold, and to this oxyd combining with a larger proportion of ammonia; and hence, in the sudden combination, more aqueous vapour and azotic gas will be disengaged.

The greater number of the metals precipitate silver in its metallic state from its acid solutions.

Copper

Copper is frequently employed in this manner, in order to obtain pure silver. When mercury is used to separate it, when the precipitation is slowly conducted, the silver assumes a crystalline arrangement, or kind of arborescence.

Silver combines readily with sulphur by fusion, forming a brittle and fusible compound, of a blue or black colour. It is also capable of combining, both in its metallic and oxydated state, with the sulphuret of potash or soda; and is thus rendered soluble in water. By adding to this compound an acid, it is decomposed, and a compound of oxyd of silver and sulphurated hydrogen is formed.— With phosphorus, silver forms a white and brittle compound, which is decomposed by heat.

This metal enters into combination with the greater number of the others. With gold, it forms what is termed Green gold. Copper renders it harder without much impairing its ductility; and such an addition is commonly made to silver used as coin or wrought into vessels. By cupellation, silver is freed from the other metals with which it may have been united, gold excepted. To free it from this metal, it is dissolved in nitric acid,
which

which leaves the gold undissolved. Muriatic acid is added to the solution, which combines with the silver, and leaves the copper, or other metals that may have been mixed with it, dissolved. The muriat of silver, after being dried, is mixed with an equal weight of potash, and exposed to heat; the metal is reduced; and in this way the purest silver may be obtained.

Silver, amalgamated with mercury, is applied to the surface of copper, or other metals; the mercury is afterwards driven off by heat, and the silver remains adhering to the surface.

The solution of silver in nitric acid is of much use as a chemical test to discover the muriatic and sulphuric acids.



Sect. IV. — — QUICKSILVER.

QUICKSILVER, or Mercury, differs from the preceding metals, in being oxydifiable in atmospheric air at a high temperature; but it resembles them in its oxyds being reduced by heat. It is distinguished from every other, by its fluidity at any common natural temperature. At 40° below 0 of Fahrenheit, it becomes solid.

Mercury is found native, in small globules appearing on its ores, or even on other fossils in the mines of these ores, and alloyed with different metals, particularly silver. It is found in greater abundance mineralised by oxygen, by sulphur, and by the sulphuric and muriatic acids. With oxygen it forms the Hepatic ore, which is supposed to be native oxyd of mercury with bituminous matter, frequently mixed with sulphuret of mercury and oxyd of iron. With sulphur, two kinds of ores are formed; the native Ethiops, and native Cinnabar. The former is more rare; its colour is
black,

black, without lustre or transparency; it is of a loose consistence. Cinnabar occurs massive and crystallized; is of a red colour, with a lustre in the massive 1.2., in the crystallized 2.3.; transparency in the latter 1.2.; and hardness varying from 3. to 8. It yields from 35 to 78 of quicksilver. The Horn quicksilver ore, which is met with in small crystals, or forming an incrustation on cinnabar, is the oxyd of the metal combined with sulphuric and muriatic acids, the proportions of these varying.

Native mercury, or any of its amalgams, is merely exposed to heat in close vessels to obtain the metal. When combined with sulphur, it is heated with one third of its weight of iron, which attracts the sulphur, and the mercury distils over.

Quicksilver has a specific gravity equal to 13.6. Although fluid, its opacity is equal to that of any other metal; and its surface, when clean, has considerable lustre. When rendered solid by a reduction of temperature, it possesses both ductility and malleability. In becoming solid, instead of expanding like other metals, it contracts. Exposed

ed to the temperature of 600° or 550° , it is volatilised.

At a temperature nearly the same as that at which it boils, mercury is capable of combining with oxygen: when heated to that point in contact with atmospheric air, its lustre is diminished, and a red sparkling powder is slowly formed, which is the oxyd of the metal. It contains in the hundred little more than 7 parts of oxygen; on exposure to a low red heat, the oxygen is expelled. Mercury can likewise be oxydated by friction or agitation, at the common temperature of the atmosphere; at least it can thus be converted into a black powder; and Dr. Priestley found that during the process the oxygen of the atmospheric air is diminished, and that the powder may be reduced to running mercury by exposing it to heat. This oxyd is formed more readily when the metal is triturated with any substance capable of dividing it more completely, as any unctuous or viscid matter. It must contain less oxygen than the red oxyd. Both are used in medicine, and the latter is the basis of several preparations.

The

The greater number of the acids act upon mercury, or are at least capable of combining with its oxyds.

Sulphuric acid scarcely acts upon it, but when concentrated and assisted by heat; it is then in part converted into sulphureous acid, by the metal attracting its oxygen; and the oxyd combines with the portion of sulphuric acid not decomposed. This sulphat of mercury remains in the form of minute crystals. There seem to be two salts of this kind; one, consisting of the perfect oxyd with an excess of acid, which has a sour taste, is very caustic, deliquescent, and soluble in water; the other, of the imperfect oxyd, combined with less acid, is a neutral salt, less soluble than the other, and affording, by evaporation of its solution, prismatic crystals. These salts generally exist together in the same saline mass produced by the action of sulphuric acid upon mercury, but in different quantities, according to the circumstances of the solution; the former being produced in greatest abundance when a large quantity of sulphuric acid is used, and the solution rendered rapid by a high temperature. When the application of heat to either of these salts is continued, more of the acid is decomposed; the
metal

metal is highly oxydated while there is not a sufficient quantity of acid to saturate it. If a quantity of boiling water is poured on this mass, it dissolves the sulphat of mercury; and the perfect oxyd which is present, and which has still a portion of acid adhering to it, acquires a lively yellow colour. This yellow oxyd is reduced by exposure to heat, affording oxygen and a small portion of sulphuric acid. It is the pharmaceutical preparation formerly termed Turbith Mineral. Sulphated mercury is decomposed by the fixed alkalis and lime, and a yellow oxyd is precipitated. Ammonia, in precipitating this oxyd, partially decomposes it; its hydrogen attracting part of its oxygen, and changing it into a less perfect oxyd, of a grey colour.

Nitric acid acts rapidly on mercury; a large quantity of nitrous gas is discharged from its decomposition, the metal is oxydated, and combines with the remaining acid. If the acid is diluted with more than an equal part of water, the decomposition is more moderate, and the metal is only imperfectly oxydated. If again the acid is not diluted, or if, when diluted, the solution is promoted by heat, the metal is more highly oxydated.

dated. Each of these oxyds combines with the nitric acid, and salts are formed soluble in water, crystallizable, and extremely caustic. The difference between these salts is rendered very evident by adding an alkali, particularly ammonia: from the one, a deep grey or black precipitate is thrown down; from the other, a white precipitate — differences arising from the difference in the oxydation of the metal.

If either of these compounds be exposed to heat, a further decomposition of the acid takes place; the mercury attracts more oxygen, and a large quantity of nitrous gas is expelled. A red mass remains, of a brilliant sparkling appearance, which is a perfect oxyd of mercury, still retaining a small portion of acid, which renders it corrosive. It is what is termed the Red Nitrat of Mercury.

The combinations of the oxyds of mercury with the nitric acid, are decomposed by the alkalis and several of the earths. Either of the fixed alkalis or lime, added to the solution made without heat, and with a diluted acid, throws down a greyish precipitate, and from the solution made under the opposite circumstances, a precipitate of
a yel-

a yellow colour; the alkali in both cases combining with the acid, and separating the mercurial oxyd.

Ammonia exerts on the nitrats of mercury a more peculiar action. Added to that solution in which the metal is imperfectly oxydated, it produces a precipitate of a dark blue colour, approaching to black: this is the mercury in its lowest state of oxydation; it is even less oxydated than it was while combined with the nitric acid; the hydrogen of the ammonia attracting part of its oxygen in the moment of its separation. This is the ash-coloured precipitate of mercury which is employed in medicine, as one of the mildest preparations of the metal.

When the ammonia is added to that solution in which the mercury exists in a more highly oxydated state, a precipitate is thrown down, grey or nearly white. This, as Fourcroy has ascertained, is not a pure oxyd, but is a ternary compound of the metallic oxyd with a portion of the nitric acid with which it was united, and of the ammonia by which it is separated.

As it is difficult to obtain a mercurial solution in which the metal does not exist in greater or less quantity in both states of oxydation, it generally happens that, from the addition of ammonia to these solutions, both precipitates are produced—the black is first thrown down, and afterwards the white; and from the mixture of these, a grey or light blue precipitate is formed. In preparing the ash-coloured precipitate for medicinal use, the circumstances productive of this mixture are to be carefully avoided; and by using a diluted acid, and avoiding the application of heat, that solution is to be obtained in which the metal exists most nearly in the state of imperfect oxyd.

Mercury is not acted on by the muriatic acid, as the metal is unable to attract the oxygen of the water present. But it is dissolved by the oxygenated muriatic acid, and its oxyds combine with facility with the simple acid. The compounds thus formed are different according to the state of oxydation of the metal. With the perfect oxyd, the muriatic acid forms a compound highly corrosive, soluble in water, and crystallizable; with the other, a compound which is, on the contrary, entirely insipid, mild, and insoluble. The

former is termed the Corrosive Muriat of Mercury; the latter, the Mild Muriat: both are employed in the practice of medicine.

When muriatic acid is added to a solution of mercury, there is generally, perhaps always, more or less of both these compounds formed, the quantity of each being proportioned to the circumstances under which the solution has been made, by which the metal is more or less oxydated. If the oxygenated muriatic acid is added, the compound produced is principally the corrosive muriat. The usual process, however, by which this is prepared is, to expose to heat a mixture of sulphat of mercury and muriat of soda, or a mixture of nitrat of mercury, muriat of soda, and dried sulphat of iron. In the former case, a double decomposition takes place, the sulphuric acid combining with the soda of the muriat of soda, and the muriatic acid uniting with the oxyd of mercury: in the latter, the sulphuric acid of the sulphat of iron combines with the soda of the muriat of soda, and the muriatic acid disengaged combines with the oxyd of mercury of the nitrat of the metal. The product in both processes is the *corrosive muriat* of mercury. It is sublimed by the heat applied, and, condensing

denfing in the upper part of the vefſel, forms a hard white cake. This again is converted into the *mild muriat*, by triturating it with nearly its own weight of running mercury till the globules are extinguifhed, and expofing it in a matrafs to a moderate heat. The metallic mercury which has been added attracts part of the oxygen of the corroſive muriat, ſo that the whole is converted into the ſtate of imperfect oxyd : this is ſaturated by the muriatic acid, which likewise exiſted in the corroſive muriat,—and thus the mild muriat is formed. To free it from any portion of corroſive muriat with which it may be mixed, it is repeatedly ſublimed.

Of theſe compounds, the corroſive muriat poſſeſſes all the properties of a ſalt. It is ſoluble in 16 parts of water at the temperature of 60° : by evaporation of its ſolution, cryſtals are formed, which are neither efflorefcent nor deliqueſcent : it changes ſeveral of the vegetable colours to a green : it is volatilifed by heat, without being changed : its taſte is harſh and ſtyptic : it is corroſive and highly poiſonous.

The

The mild muriat has properties entirely opposite. It is completely insoluble in water, is tasteless, and mild in its operation : it is volatilised by heat ; and when the sublimation of it is slowly conducted, a loose mass of prismatic crystals is obtained : its specific gravity is much greater than that of the corrosive muriat.

Both these compounds are decomposed by the alkalis, different products being obtained. When potash, soda, or lime, is added to a solution of the corrosive muriat, a yellow oxyd is immediately precipitated ; when ammonia is added to the same solution, a white precipitate is formed. This is not a pure oxyd, but, according to the analysis of it by Fourcroy, is a ternary combination of oxyd of mercury, muriatic acid, and ammonia ; the proportions of its principles being 81 of the first, 16 of the second, and 3 of the third. It is the white precipitate of mercury of the pharmacopoeias. The common mode of preparing it is, to dissolve equal parts of corrosive muriat of mercury and muriat of ammonia in water, and add the same quantity of the solution of pure potash ; the potash disengages the ammonia of the muriat
of

of ammonia, and this decomposes the muriat of mercury, forming the white precipitate.

When either of the fixed alkalis or lime is added to the mild muriat of mercury, a greyish precipitate is thrown down, which is merely the oxyd that was combined with the muriatic acid. When ammonia is added, the precipitate is of a darker colour, and is indeed nearly black, because the ammonia in separating it from the acid, likewise partially de-oxydates it; it is therefore nearly, if not precisely, the same as that precipitated by ammonia from the nitrat of mercury.

Mercury is scarcely acted on by any of the other acids; its oxyds, however, combine with the greater number of them, and form peculiar compounds. These combinations may be effected by digesting the oxyd in the acid; but a more easy mode is to add to the nitrous solution of mercury either the pure acid designed to be combined with the mercury, or some neutral salt which contains it. If, for instance, phosphoric acid be added to the nitrous solution of mercury, a phosphat of mercury is formed; or if, instead of the acid, a solution of phosphat of soda be added, the same compound

pound is obtained, — the soda attracting the nitric acid, and the phosphoric acid combining with the oxyd of mercury. In the same manner may be effected the combination of the oxyds of this metal with any other acid.

The oxyds of mercury precipitated by the alkalis, especially by ammonia or lime, if dried with exposure to light, and triturated with 1-6th of their weight of sulphur, detonate on being heated. Of late, a more powerful fulminating preparation has been discovered by Mr. Howard. It is obtained by dissolving 100 grains of mercury in $1\frac{1}{2}$ ounce of nitric acid, with the assistance of heat; the solution when cold is *poured upon* 2 ounces of alcohol by measure; a moderate heat is applied, till an effervescence is excited, and a precipitate is formed; this, washed and dried, forms the fulminating mercury: $1\frac{1}{2}$ or 2 grains of it, struck upon an anvil, explodes violently; and the same effect is produced by a strong electrical discharge, by strong friction, or exposure to heat. Mr. Howard found this preparation to consist of oxyd of mercury, oxalic acid, and nitrous etherised gas. Its detonation is owing to the sudden combination of the oxygen with the carbon and hydrogen of these

these substances, forming aqueous vapour and carbonic acid, and disengaging azotic gas, while, at the same time, so much caloric is let loose, that not only the elasticity of these gases is much increased, but even the metal, it has been proved by Mr. Howard's experiments, is converted into vapour:

Quicksilver combines with sulphur. By mere trituration together, the mercurial globules are extinguished, and a black powder is formed, which seems to result from the combination of the two substances. It is the black sulphuret of mercury. When 7 or 8 parts of the metal are triturated with one of sulphur, and the black powder they form is subjected to a moderate heat in glass vessels, a more intimate combination of them is effected, while the metal seems further to be slightly oxydated; — a sublimate is obtained of a fine red colour. This is the red sulphuret of mercury, the cinnabar or vermilion of commerce.

Mercury is acted on by the alkaline sulphurets when these are dissolved in water; it seems to attract sulphurated hydrogen. These compounds, especially

cially that from the sulphuret of ammonia on exposure to the air, assume a red colour, and form a compound similar to cinnabar.

Mercury does not unite with carbon; it combines with phosphorus, forming a tenacious concrete mass, fusible, and decomposed by heat.

Quicksilver combines with many of the metals; it has not been practicable to unite it with iron, cobalt, antimony, or nickel: it unites with platina with great difficulty. These compounds are brittle and soft, and when the mercury is in large proportion, are fluid. They are termed amalgams. The amalgam of it with tin is used in silvering glasses; that with gold, or silver, in gilding or silvering the other metals,

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 Sect. V. — — COPPER.

This metal is of a red colour with a shade of yellow, and is inferior in lustre, malleability, and ductility, to the more perfect metals as they are termed, but is harder than silver or gold. Its specific gravity is from 8000 to 9000.

Copper is found native, in a massive, arborefc- cent, or disseminated form, having the colour of the pure metal, frequently tinged of various shades. Lustre, 2.1. Hardness, from 6. to 7. Specific gravity from 7.6. to 7.8. Combined with oxygen it forms the red or ruby copper, which is found massive, disseminated or crystallized, of a red colour, moderate lustre, hard, and brittle. The green sand of Peru is another oxyd of the metal, which, from the accidental mixture of sea salt, was formerly supposed to be a muriat of copper. The oxyd of copper united with carbonic acid forms

the ores termed Mountain Green and Mountain Blue, found interspersed, incrusting other ores, in earthy masses, and crystallized. The compact green ore of this kind is termed Malachite. The arseniat of copper, or native combination of the metal with arsenical acid, is found generally in cubical or prismatic crystals, of a green colour, considerable lustre and transparency. The vitreous copper ore, which is of a grey colour, and metallic splendour, consists of copper and sulphur; it occurs in masses, interspersed, or crystallized. The purple, grey, and black ores, differ from it in containing iron, and frequently other metals. The yellow copper ore, or copper pyrites, contains a still larger proportion both of iron and sulphur.

To extract copper from its matrix, when found native, fusion is sufficient; when it is mineralised, the fusion must be repeated a number of times, and the product is lastly melted in contact with the fuel.

Copper tarnishes on exposure to air and moisture, and becomes covered with a green oxyd. It is fused by a strong white heat. At a temperature inferior to that which melts it, if heated

ed in contact with atmospheric air, it is oxydated, thin scales forming on its surface. These consist of the brown oxyd, which, if exposed to a long continued heat, attracts more oxygen, and forms an oxyd of a deep red colour. When copper is intensely heated, or when deflagrated with nitrat of potash, it burns with a green flame. These oxyds are not decomposed by heat alone; they may be reduced by heating them with charcoal.

Copper is readily acted on by the greater number of the acids. The sulphuric, when concentrated and assisted by heat, oxydates and dissolves it,—as does also the diluted acid. The solution is of a blue colour, and affords by evaporation regular crystals. These are permanent in the air, soluble in 4 times their weight of water at the temperature of 60°, and decomposed by heat, the acid being expelled. They consist of 27.68 of acid, 35 of metallic oxyd, and 37.32 of water. This salt is the *blue vitriol* of commerce; it is found dissolved in the waters in copper mines, from which it is extracted; and it is also prepared on a large scale by the decomposition of copper pyrites, or native combination of copper and sulphur.

Nitric

Nitric acid acts on copper with rapidity ; a large quantity of nitrous gas, mixed even with nitrous oxyd and azot, being disengaged. The solution is green or blue according to the strength of the acid by which the metal has been more or less oxydated. It affords by evaporation crystals very deliquescent, soluble in water, and easily decomposed by heat. Nitrat of copper has a singular effect upon tin. If a quantity of it powdered be spread upon tin foil, slightly moistened, and quickly rolled up, nitrous fumes are soon disengaged, the metal becomes hot, and is inflamed. This is ascribed to the nitric acid being rapidly decomposed by the tin attracting its oxygen, whence a large quantity of caloric is extricated, along with light.

Although copper is unable at any temperature to decompose water, muriatic acid, by its strong disposing affinity, enables it to effect this decomposition and attract oxygen. This acid likewise combines with the oxyds of copper, and even attracts them from the sulphuric and nitric acids. The muriat of copper is deliquescent, and very soluble in water.

Copper

Copper is slowly oxydated by several of the other acids, at least when exposed to their action in contact with atmospheric air, the disposing affinity of the acid causing the metal to be oxydated by the air. Hence the most acid vegetable juices may be boiled with safety in copper vessels, the steam excluding the air; while if allowed to stand in them when cold, a crust of oxyd of copper, or rather of the combination it forms with the acid, is soon formed at the side of the vessel in contact with the liquor. — The phosphoric, carbonic, and other acids may be combined with the oxyds of copper, by adding some of their neutral salts to a solution of sulphat or nitrat of copper. The combination with the acetic acid prepared by stratifying copperplates with vinegar, is of a fine green colour, and is used in painting, and in medicine, under the name of Verdigrease.

The salts of copper are decomposed by the alkalis and earths, If either potash or soda is added to their solutions, it combines with the acid, and an oxyd is thrown down, of a colour varying from grey to green or blue, according to the state of oxydation. The action of ammonia is singular. It likewise throws down the oxyd; but if more ammonia

ammonia be added, it combines with it, and forms a transparent solution of a deep blue colour. It exerts the same action upon any of the oxyds of the metal, and it even acts upon the metal itself, enabling it, by a disposing affinity, to be oxydated by the atmospheric air. — The combination of ammonia and oxyd of copper, when slowly evaporated, affords crystals of a dark blue colour. It is likewise obtained in a solid form, mixed with sulphat of ammonia, by triturating together three parts of carbonat of ammonia with two of sulphat of copper; this forms a compound, known in medicine by the name of Ammoniated Sulphat of Copper. Some of the other precipitates of copper are used as pigments, as the Brunswick green, prepared by triturating muriat of ammonia with copper filings; and Verditer, obtained by precipitating the nitrat of copper by lime.

Copper is precipitated from its solutions by several other acids, as by iron or zinc, which have a stronger attraction to oxygen than it has. In such cases, it is precipitated in its metallic state.

Copper

Copper and sulphur unite by fusion; the compound is grey and brittle, and more fusible than the copper itself. Sulphuret of potash combines with copper both in the humid and dry way; and the metal, as well as its oxyds, attract sulphurated hydrogen. Phosphorus can be combined with copper, by heating the metal with phosphoric acid and charcoal; the compound has the metallic lustre, is hard and brittle, and is decomposed by heat.

Copper is capable of combining with the greater number of the metals. It unites with difficulty with iron; with zinc it forms the compound metals, brass, pinchbeck, and others; with tin, bell-metal and bronze.

Sect. VI. — — *IRON.*

This metal, the most useful of all others, is diffused in great abundance in nature. It is found in the earth combined with other substances earthy
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and metallic, and few fossils indeed are entirely free from it ; it is contained in the waters of rivers and springs ; it exists in a variety of vegetable products, and is obtained from their ashes ; and it is a component part of the blood, and of several other animal fluids and solids. From its existence in so many organic beings, it has been supposed to be formed by the processes of the living system, and experiments have even been stated in support of this opinion, which scarcely, however, authorise the conclusion.

Mineralogists have disputed with respect to the existence of native iron : it seems now to be generally admitted, and immense masses of it have been found, which could not have been the product of art.

Iron is frequently mineralised by oxygen, forming what are termed the Calciform ores, of which the principal varieties are the black, or magnetic, iron stone, found both amorphous and crystallized, and in the state of sand : specular iron ore, likewise found crystallized and in masses, and distinguished by its lustre, and frequently by its iridescent colours : the brown and red hæmatites,

minerals, which are generally amorphous, and which contain several heterogeneous ingredients besides oxyd of iron : several ores, known by the vague name of Iron Stones, and containing more or less argillaceous earth, and frequently lime and flint, with oxyd of iron ; and lastly, the ochres in which the proportion of argillaceous earth is still greater. Combined with silver it forms the pyrites, which is very abundant, and found in a variety of forms, amorphous and crystallized, of a yellow colour and metallic lustre, and varying in composition, the sulphur being sometimes in larger proportion than the metal, and sometimes the reverse. In the *micaceous iron ore*, the metal is combined with carbon ; in the *blue martial earth*, with carbon and phosphoric acid ; in the *arsenical iron ore*, with arsenical acid ; in the *sparry iron ore*, with carbonic acid, manganese, and lime ; and in *emery*, with siliceous earth.

The general process by which iron is extracted from its ores, is first to roast them by a strong heat, expel the sulphur, carbonic acid, and other mineralisers which can be separated by heat. The remaining ore, being reduced to small pieces, is mixed with charcoal or coke, by which, when

exposed to an intense heat in a close furnace, the oxyd is reduced. There are likewise some additions necessary to serve as a flux to vitrify the scoria, and facilitate the separation of the melted metal. The matrix of the iron ore is generally either argillaceous or calcareous, or sometimes a portion of siliceous earth; but whichever of these earths is present, the addition of one or both of the others makes a proper flux. These are accordingly added in the proper proportion according to the nature of the ores; and this mixture in contact with the fuel, is exposed to a heat sufficient to reduce the oxyd, and melt the iron,

The metal thus obtained is termed Cast Iron, or Pig Iron. It is far from being pure; besides several heterogeneous ingredients, it always contains carbon and oxygen. According as one or other of these predominates, the quality of the cast iron is different. Where the oxygen is present in a large proportion, the colour of the iron is white, it is extremely brittle, and its fracture exhibits an appearance of crystallization: where the carbon exceeds, it is of a dark grey inclining to blue, and is less brittle. The former is the white, the latter the black crude iron of commerce.

merce. The grey is intermediate between them in qualities and composition. In any of these states, the iron is much more fusible than when pure; hence it can be fused and cast into any form; it is also, however, much more brittle, and cannot therefore be flattened under the hammer.

To obtain pure iron, or free it from the carbon and oxygen with which it is combined in the crude iron, it is subjected to the operations of melting and forging. By the former, in which the metal is kept in fusion for some time, and constantly stirred, the carbon and oxygen are combined, and the product is expelled: the metal at length becomes viscid and stiff; it is then subjected to the action of a very large hammer, or to the more equal, but less forcible, pressure of large rollers, by which the remaining oxyd of iron, and other impurities not consumed by the fusion, are pressed out. The iron is now no longer granular in its texture; it is soft, ductile, malleable, and much less fusible. It is termed Forged, or Bar, Iron, and is the metal in its pure state.

There

There are still some varieties of this iron, arising from intermixture of other substances. Pure iron is distinguished by its great infusibility, its softening when heated, and its being ductile and malleable at every temperature. There is one kind of forged iron, which, when cold, possesses this ductility, but when heated, is extremely brittle, and is also fusible: this is termed Hot Short Iron. Another variety, the Cold short iron, possesses precisely the opposite properties, being highly ductile when hot, but when cold extremely brittle. The causes of these peculiarities have not perhaps been perfectly explained. Chemists are generally agreed, that the property of cold short iron depends on the presence of a substance termed Siderite, once considered as a peculiar metal, but now known to be a compound of phosphoric acid and iron: that of hot short iron has been ascribed to the intermixture of arsenic, sulphur, or sulphureous acid; but the real cause is not well ascertained.

Forged iron, free from these peculiar properties, is malleable at every temperature, and is extremely infusible. It is the metal in its pure state. Its colour is a light grey, its texture is porous, its fracture

fracture brilliant and fine grained; its hardness is considerable; it is very malleable, and exceedingly ductile; its specific gravity is 7.788, that of cast iron 7.207.

Iron is distinguished from every other metal by its magnetical property; it is attracted by the magnet, and acquires by itself, under various circumstances, the property of magnetism. It has been supposed to be the only substance in nature capable of acquiring this property; but this appears to belong likewise, though in a less degree, to some other metals, particularly to nickel.

The magnetic property remains in several of the oxyds of iron, but beyond a certain degree of oxydation it is lost.

Pure iron is extremely infusible, and, when not in contact with the fuel, cannot be melted by the heat which any furnace can excite. It is, however, softened by heat, still preserving its ductility: this constitutes the valuable property termed *welding*, by which two pieces of iron heated, and beat together, are firmly joined.

When

When iron is heated in contact with atmospheric air, it is oxydated, and scales are formed on its surface. This first oxyd contains from 20 to 25 parts of oxygen in the 100. Reduced to powder, and exposed to heat, it acquires a red colour, and absorbs more oxygen, equal to 32 or 34 parts. In oxygen gas, a fine iron wire, previously heated to ignition, burns with great splendour, and iron filings at a high temperature deflagrate with nitrat of potash. None of the oxyds of iron are decomposed by heat, but they may be reduced by exposing them to heat mixed with charcoal.

Iron is oxydated even at a low temperature by exposure to the air: this forms what is termed in common language *rusting*. It is favoured by moisture; and experiments have shewn, that tho' the oxygen of the air is partly abstracted during the process, yet a slow decomposition of the water takes place; and even by agitation in water a similar oxydation is produced. The common rust of iron contains carbonic acid.

At the temperature of ignition, iron decomposes water with rapidity, attracting its oxygen, and the hydrogen passing off in the state of gas.

It

It is oxydated and dissolved by the acids. The sulphuric acid, when concentrated, requires the assistance of a boiling heat; when diluted with three or four parts of water, the solution proceeds rapidly in the cold, the acid, by a disposing affinity, enabling the iron to attract the oxygen of the water, and combining with the oxyd; a large portion of hydrogen gas is of course disengaged. The solution is green, and by evaporation affords regular crystals of a fine green colour. They are soluble in 6 parts of water at a mean temperature: exposed to heat, they undergo the watery fusion, and by a stronger heat the salt is decomposed, its acid is expelled, and a brown oxyd remains: exposed to the atmosphere, it first effloresces, and, after some time, it loses its green colour, becomes yellow, and forms a loosely adherent mass. This change is owing to an absorption of oxygen by the metallic oxyd; it still, however, remains combined with the sulphuric acid, forming a salt different from the other, which is not crystallizable. The fixed alkalis throw down from it a yellow precipitate, while, from the other, they separate a green. The former of these salts absorbs nitrous gas, and has been proposed as a mean of ascertaining the quantity of azot that may be mixed with this gas,

as the azotic gas is not absorbed; but, according to Berthollet, the diminution of volume which nitrous gas suffers from sulphat of iron, is owing to its decomposition; the oxygen combining with one part of the azot, and forming nitrous gas, and the other part of the azot remaining uncombined.

Nitric acid is rapidly decomposed by iron. When diluted, the solution goes on more slowly, the metal is less highly oxydated, and more of it is dissolved. The solution does not afford regular crystals by evaporation: it is decomposed by a very moderate heat, and absorbs oxygen when exposed to the air.

Muriatic acid dissolves iron with ease, first enabling the metal to decompose the water present, and then combining with the oxyd; hydrogen gas is therefore at the same time disengaged. The solution by evaporation may be brought to the consistence of a syrup, when it deposits small needle-like crystals. When exposed to the air, it undergoes the same changes as the other solutions of iron do, though more slowly, and the greater part of the oxyd is deposited.

Carbonic

Carbonic acid is capable of combining with iron. The combination is effected by keeping an iron wire in a saturated solution of carbonic acid in water. In the natural chalybeate waters, the iron is, with few exceptions, held dissolved by this acid.

Phosphoric acid dissolves this metal; the compound is nearly insoluble in water. The boracic and fluoric acids likewise combine with it. A peculiar animal acid, the Pruffic, has a strong attraction to its perfect oxyd; it forms with it an insoluble compound, of a rich blue colour, the Pruffian blue of commerce. Another acid, of vegetable origin, the Gallic, combines with the same oxyd, and forms a precipitate, of a deep purple, or black colour. Both these combinations are afterwards to be noticed; they are the most delicate tests we possess for discovering the presence of this metal.

The combinations of iron with the acids are decomposed by the alkalis and several of the earths, the oxyd being precipitated, and varying in its colour from the different solutions according

to its degree of oxydation. In general, part of the precipitate is redissolved by the alkali, and still more by the alkaline carbonats.

As iron has a stronger attraction to oxygen than any other metal, zinc and perhaps manganese excepted, these are the only ones capable of precipitating it from its solutions.

Iron has a strong attraction to carbon; their combination produces steel, one of the most useful forms of this valuable metal. To form steel, bars of malleable iron are bedded in charcoal in a close furnace, alternate layers of iron and charcoal being formed. A strong fire is applied for six or eight days; the progress of the cementation, as this process is termed, is known by drawing a trial bar from the furnace: if this is sufficiently changed, the fire is extinguished, and the metal is left to cool for six or eight days. This forms Blistered steel: it is rendered more perfect by subjecting it to the operation of the hammer, as in forging iron; or it is fused and cast into small bars, forming what is termed Cast steel. These operations are performed on malleable iron; but those kinds
of

of cast iron which contain little oxygen can be converted into steel by a similar process.

In this operation, an increase of weight from $\frac{1}{10}$ th to $\frac{1}{2}$ th is gained. The more carbon is introduced, the more brittle is the steel. Bergman first clearly shewed the presence of this matter, by ascertaining by experiments that less hydrogen is disengaged during the solution of steel in diluted sulphuric acid, than during the solution of iron in the same acid; and that during the solution of the steel, carbon is precipitated in the form of plum-bago. Morveau has justly observed, that it is pure carbon, not its oxyd, that is present in steel; and to this, its great hardness may be ascribed. Bergman further found, that some specimens of steel contained manganese and siliceous earth; and Vauquelin has likewise discovered the existence of this earth and of phosphorus in several kinds of steel which he analysed.

Steel is of a grey colour; its fracture is granular and brilliant, and it is susceptible of a very high polish. It is more fusible than pure iron. It is both ductile and malleable, and when hammered has a specific gravity greater than that of iron.

iron. The property by which it is eminently distinguished is, that of acquiring a degree of hardness by being hastily immersed in cold water when previously heated, the hardness being greater as the steel has been hotter and the water colder. It at the same time becomes more brittle and elastic. Steel thus hardened may have its softness and ductility restored, by again heating it, and allowing it to cool slowly. This is what is termed *tempering* of it, the requisite degree of hardness being given by heating the metal more or less, and allowing it to cool slowly.

Steel possesses a degree of hardness superior to any other metal; it is also possessed of the highest elasticity: and by these properties it is rendered, perhaps, the most valuable of the metals.

Iron has a strong attraction to sulphur, and combines with it with facility by fusion. The compound is of a black colour, is brittle, and very fusible, and, like the natural pyrites, is capable of decomposing both water and atmospheric air. This decomposition likewise takes place when the iron and sulphur are merely mixed and moistened with water; when the air is excluded, the mixture

ture even inflames. Iron is likewise dissolved by the alkaline sulphurets; and its oxyds are capable of combining with sulphurated hydrogen.

With phosphorus, iron enters into combination; the compound is white, brittle, and fusible. It has been supposed that this compound is the substance once supposed to be a peculiar metal, and termed Siderite; but this is rather a compound of oxyd of iron and phosphoric acid.

Iron is capable of combining with a number of the metals. It does not unite with lead or bismuth, and very sparingly with mercury. The principal useful combination of it is that with tin, tinned iron being formed by immersing thin plates of malleable iron in melted tin, when the metals combine, not only at the surface, but thro' the substance of the iron.

This metal does not combine with the earths, but its oxyds do, and communicate to glasses various shades of colours.

SECT. VII. — — TIN.

THIS metal is of a greyish white colour ; lustre 3. hardness 6. ; it is considerably malleable, but possesses very little ductility. It is the lightest of all the metals, its specific gravity when hammered being 7.299.

Tin is comparatively a rare metal, as it is not found in great quantity any where but in Cornwall in England. It is distinguished also as existing only in the primitive mountains. It has been much doubted whether it is ever found native ; in the opinion of Mr. Kirwan, there are sufficient authorities to determine the question in the affirmative, though specimens of native tin are extremely rare. The native oxyd is an abundant ore ; it occurs both massive and crystallized : its colour is brown, or brownish black : the forms of the crystals

crystals are very irregular; their lustre 2.3, transparency 1.2.3, hardness not less than 10. When massive, it is destitute of lustre and transparency. The crystals contain in the 100 parts 77 of metal and 23 of oxygen.—The Wood tin ore is another variety of the native oxyd, termed so from its fibrous texture; it contains about 63 parts of metal in the 100. Tin is also mineralised by sulphur, associated always with a portion of copper, and often of iron; the colour of this ore is a yellowish grey, with a metallic lustre, and no transparency. It consists of 25 of sulphur, 36 of copper, and 34 of tin. To extract tin from its ores, the ore is slightly roasted, is pounded and washed, and is melted in contact with the fuel.

Tin is the most fusible of the metals. It melts at about the 410th degree of Fahrenheit's scale. By an intense heat it is volatilised. At a moderate heat, in contact with atmospheric air, it is quickly oxydated; its surface is covered with a greyish powder, which, if heated to ignition, becomes white from the absorption of more oxygen. This white oxyd is likewise formed by heating the metal to a red heat in atmospheric air: by deflagrating the tin with nitrat of potash, part of it is so highly

highly oxydated as to approach to the nature of an acid, and remain combined with the potash. The white oxyd is by itself very infusible ; when melted with vitrifiable substances, it forms an opaque white glass, which is the basis of enamel.

Tin is oxydated and dissolved by several of the acids. With the assistance of a moderate heat, it decomposes the concentrated sulphuric acid, a large quantity of sulphureous acid being disengaged : the solution on standing deposits slender crystals. Water decomposes it, attracting its acid, and precipitating its oxyd.

Nitric acid is decomposed by tin with great rapidity. If the acid is in a certain state of strength, no gas is disengaged ; but on adding a quantity of lime, ammonia is disengaged : in this case the alkali has been formed ; the tin decomposing both the acid and the water, and the hydrogen of the one and azot of the other combining, by being presented to each other in their nascent state. The tin is so highly oxydated, that little of it combines with the acid. When the acid is weaker, a quantity of nitrous gas, mixed with nitrous oxyd and azot, is disengaged ; but still the metal is so
highly

highly oxydated, that a small portion only of nitrat of tin can be obtained.

Muriatic acid dissolves tin. During the solution, a quantity of hydrogen gas is disengaged, from the decomposition of the water by the metal: the solution is transparent, and of a yellowish tinge: by evaporation, it affords needle-like crystals on exposure to the air. These consist of the imperfect oxyd of tin combined with the acid. This salt has a great avidity for a further portion of oxygen; and hence it absorbs oxygen gas, and decomposes oxygenated muriatic acid, nitric acid, nitrous gas, fulphureous acid, and several metallic oxyds. The salt, with the perfect oxyd, differs from the former: it is crystallizable, but is also volatile, and may be easily distilled; a liquor of a thick consistence is obtained, which emits white fumes of a penetrating smell: by the addition of water, it is decomposed, and oxyd of tin precipitated.—The oxygenated muriatic and nitro-muriatic acids dissolve tin with great facility. The solution in the latter acid, when care is taken that it shall be slowly performed, is transparent and brown-coloured; it soon becomes gelatinous, and

at length firm. It is decomposed by water: if the water is added to the fluid solution, it renders it concrete, from the copious precipitation of oxyd of tin. This solution is used in dyeing, as a mordant to heighten and fix several colours.

The other acids are capable, either of oxydating tin, or of combining with its oxyds; but the compounds thus formed are not important.

The alkalis appear to have some action on this metal, and, when assisted by heat, to be capable of dissolving a small portion of it both in the reguline state and in that of oxyd.

Tin combines with sulphur by fusion. The compound is much more infusible than the metal, is of a dark grey colour, and retains the metallic splendour. With the perfect oxyd of tin, sulphur forms a compound, of a golden colour and brilliant appearance, termed *aurum musivum*. It may be prepared by different processes; but the usual one is to amalgamate 12 parts of tin with 3 parts of mercury, by adding the latter to the tin melted, and afterwards triturating the mass. This amalgam is intimately mixed by trituration with
7 parts

7 parts of sulphur and 3 parts of muriat of ammonia: the mixture is exposed to heat in a matrass as long as any white vapours are disengaged: the heat is then moderately increased; a little sulphuret of mercury, and some oxygenated muriat of tin sublime, and the ~~aurum~~ ~~argentum~~ remains at the bottom of the matrass.

The theory of the formation of this compound is one of the most intricate in chemistry; but it appears to have been sufficiently ascertained by the researches of Pelletier. In the first amalgamation and trituration of the mercury and tin, the latter is divided, and in some degree oxydated: when the mixture of this amalgam with the sulphur and muriat of ammonia is heated, the muriatic acid, by a disposing affinity, enables the tin to be oxydated by decomposing the water, and this oxyd combines with the muriatic acid; the hydrogen of the water is disengaged with the ammonia of the muriat of ammonia, this ammonia unites with a portion of the sulphur, and forms sulphuret of ammonia, which, being disengaged, causes the white fumes. The heat being now augmented, the muriat of tin is again decomposed, the oxyd of the metal attracting a portion of sulphur, and forming

forming the *aurum musivum*. In conformity to this theory, Pelletier found that, by combining oxyd of tin and sulphur by several more simple processes, the same compound was formed.

Sulphuret of potash combines with tin by fusion : the compound is partly soluble in water : if an acid is added to the solution, the tin is precipitated in combination with sulphurated hydrogen.

Tin combines with phosphorus ; the compound has the metallic brilliancy, but is so soft that it can be cut with a knife. Tin does not unite with carbon.

With the greater number of the metals, tin combines with facility. Of these alloys, that with mercury is used in silvering mirrors ; that with copper forms the compound metals bronze and bell-metal ; and that with zinc, bismuth, and lead, forms pewter. It is also applied to the surface of copper and iron, forming tinned plates of these metals.

Sect. VIII. — — *LEAD.*

LEAD is of a light blue colour, with a lustre equal to 3, but which very quickly tarnishes. It is the softest and least elastic of the metals, its hardness being only 5. It possesses little malleability, and still less ductility. Its specific gravity is 11.435; it is, therefore, the heaviest metal, next to gold and platina.

Lead has been said to be found native, but it is very rare. Native oxyd of lead is sometimes intermixed with clays and other earths, generally combined with a portion of carbonic acid. Carbonat of lead exists in considerable abundance, either massive or crystallized, of a white colour with shades of yellow or brown, brittle, of a waxy or silky lustre, having in general little transparency: it contains from 18 to 24 parts in the

100 of carbonic acid, and very generally small portions of iron and lime. Phosphat of lead is of a green colour of various shades, with a waxy lustre; occurs likewise both amorphous and crystallized: it contains from 70 to 72 of lead in the 100, with 18 of the phosphoric acid, and a small portion of iron to which its green colour has been ascribed. Sulphat of lead has been found in small transparent crystals, of a yellowish white colour, and considerable lustre. Arseniat of lead is a rare ore; it is of a green colour, passing into yellow with a degree of transparency. Molybdat of lead, or the combination of the metal with the metallic acid termed Molybdic, is more abundant; it occurs massive, or in small cubical crystals, of a yellow colour, and waxy lustre. The last of the native salts of lead is that in which it is united with the newly discovered metallic acid, the acid of Chrome, forming the Red Lead of Siberia. Lastly, lead is mineralised by sulphur, forming the compound termed Galena, which is by far its most abundant ore. In colour, lustre, and specific gravity, it is very similar to the metal, its texture is foliated, compact or granular. It occurs both crystallized and in masses, and its surface is often iridescent. The lead exists in it in the metallic state.

the

the proportion varying from 45 to 83 parts in the 100. It always likewise contains a portion of silver varying from $\frac{1}{12}$ to $\frac{1}{10}$.

Lead is easily extracted from its ores; the native salts of it are decomposed, and the oxyd reduced, by fusing them in contact with the fuel; the galena is roasted to expell its sulphur, and the lead is melted out,—iron or lime being sometimes added to abstract the sulphur more completely.

Lead melts at about 540° of Fahrenheit; and by an intense heat may be volatilised. When melted in contact with atmospheric air, it is soon covered with a thin pellicle, which is the imperfect oxyd of the metal. By exposing this grey oxyd to a stronger heat, it acquires a lively yellow colour, forming the pigment termed Mafficot: if the application of the heat be continued, its colour changes to a bright red, when it is termed Minium. By a higher temperature it is semi-vitrified, forming litharge, and by a still stronger it forms a perfect glass. The red oxyd of lead, which contains about 12 parts of oxygen in the 100, yields part of this oxygen on exposure to a red heat, but is not entirely reduced. The complete reduction
of

of this and the other oxyds of lead is easily effected by heating them with charcoal. Hydrogen likewise reduces them.

Though lead is incapable of decomposing water at any temperature, yet when long exposed to it, it is covered with a thin crust of white oxyd; the metal having probably attracted oxygen from the atmospheric air which water contains.

The greater part of the acids act upon lead. The sulphuric requires the assistance of a boiling heat to oxydate and dissolve any of the metal; but it combines with facility with its oxyds. Sulphat of lead is nearly insoluble in water, unless when combined with an excess of acid, by which its solubility is increased. It then affords slender crystals by evaporation. Nitric acid is decomposed by lead, and nitrous gas is disengaged; the metal is even so much oxydated, that little of it combines with the acid. If the acid has been diluted, the metal is less highly oxydated, and therefore more of it is dissolved. The nitrat of lead is soluble in water, and crystallizes; it has a sweetish astringent taste, and detonates when thrown on burning fuel. Muriatic acid acts very weakly on lead,

lead, even when assisted by heat. It combines with facility, however, with its oxyda, forming a compound nearly insoluble. It is melted by heat into a glass possessing considerable tenacity. Fluoric acid dissolves lead by the assistance of heat: carbonic, phosphoric, and boracic, combine with its oxyds, forming compounds applied to no use. With the acetous acid or vinegar, a salt is formed, the acetat of lead, or sugar of lead of commerce, much used in the arts and in medicine: its formation is to be afterwards noticed. The same acid corrodes lead, and forms an oxyd termed Ceraffe.

From these solutions, the alkalis and earths throw down a white oxyd. The alkalis, by being boiled on the oxyds of lead, dissolve a small portion of them. Several of the neutral salts are decomposed by these oxyds: the most important of these decompositions is that of the muriat of soda, which is effected by triturating 1 part of it with 4 parts of litharge, as much water being added as is sufficient to make a paste: pure soda is thus obtained. This decomposition must appear singular, since soda has a stronger attraction to oxyd of lead than muriatic acid has; it is owing, as Vauquelin has shewn, to concurrent affinities, the direct attrac-

tion of soda for muriatic acid, and the disposing attraction of muriat of lead to an excess of oxyd. Hence a large quantity of oxyd of lead is necessary to effect the decomposition, and the compound which is obtained is a muriat of lead with excess of oxyd. By exposure to heat it acquires a bright yellow colour, and is used as a pigment.

Sulphur combines with lead by fusion, and forms a compound of a dark grey colour and metallic lustre, less fusible than the metal, and decomposed by heat. Sulphurated hydrogen combines with the oxyds of lead, and forms a compound of a deep brown colour. This has been used as a sympathetic ink, letters being traced with a solution of acetat of lead, and held over a solution of sulphuret of potash, when they are soon blackened by the sulphurated hydrogen. It has also been used as a test to discover the presence of lead in wine or other liquors. If a solution of sulphuret of potash or lime be added to any liquor containing lead, a copious black precipitate is formed, consisting of sulphurated hydrogen and oxyd of lead. This test, however, is inaccurate, as it likewise precipitates iron of a brown colour. The nature of the precipitate may be discovered by

by adding to it muriatic or tartarous acid, which will dissolve it if it is iron. The test prepared by Hahneman guards against the same inaccuracy, and is more convenient. Equal parts of sulphur and powdered oyster shells are exposed to a white heat for 10 or 15 minutes: a sulphuret of lime is thus obtained, 1 dram of which is dissolved along with $3\frac{1}{2}$ drams of acidulous tartarite of potash in 8 ounces of water. One part of this solution added to four parts of the suspected liquor precipitates lead of a black colour, if it is present, but does not throw down iron. It likewise precipitates other noxious metals, copper of a dark green or grey, and arsenic of a lively yellow.

Lead combines with phosphorus; the compound retains the metallic lustre, and nearly the colour of the metal—is soft and flexible.

Lead combines with other metals, but few of its alloys are applied to any use. In the different kinds of pewter, it is present in a proportion from one-twentieth to one-fourth the weight of the mass. Two parts of lead and one of tin form an alloy very fusible, termed Soft Solder.

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The oxyds of lead promote the vitrification of the earths, and form with them dense transparent glasses.

SECT. IX.

ZINC.

ZINC is the first of those metals which, from being nearly destitute of ductility and malleability, have been improperly termed Semi-metals. It possesses some degree of malleability, as by uniform pressure it may be pressed into thin leaves. Its colour is white, lustre 3. which does not tarnish quickly; its texture is striated; hardness 6.; specific gravity 7.190.

Zinc is found in nature mineralised by oxygen, with or without carbonic acid, by sulphuric acid, and by sulphur. Native oxyd of zinc occurs in a loose and in a compact form, amorphous, of a white, yellow, or brown colour, without lustre or transparency. It contains in the 100 from 30 to 84 of zinc; the other ingredients are oxyd of iron, silica, and argil. Combined with carbonic acid, it occurs like-

likewise compact, and sometimes crystallized; its texture is striated; its lustre and transparency are moderate. It contains from 50 to 62 of oxyd of zinc with carbonic acid and water, and sometimes filix. Sulphat of zinc is found efflorescent, or in the form of stalactites, in the mines of zinc ores. Sulphuret of zinc, or blend, is the most abundant ore; it is found massive or disseminated, or crystallized, of a yellow, brown, or black colour, and with various degrees of lustre and transparency. The zinc exists in this ore in its metallic state, and in the proportion of from 40 to 65 parts in the 100. Besides sulphur, it also contains iron, lead, argillaceous and siliceous earths, and always a portion of water.

Zinc is extracted from its ores by being volatilised by heat, the vapour of the zinc being condensed in water, or received in a bed of charcoal.

This metal melts at 700° of Fahrenheit. In close vessels, by a further increase of heat it is volatilised without change. When melted in contact with the air, its surface becomes covered with a grey powder, which is an imperfect oxyd; when heated a little above ignition, it burns with a bright

bright flame, and a white oxyd is formed in light flashes, which are carried off by the rapid current of air in the burning metal. The oxyd itself is not volatile, but vitrifies when urged by an intense heat.

Zinc is not acted on by water at the usual temperature of the atmosphere; but at that of ignition, it decomposes the water rapidly, and disengages hydrogen gas.

It is oxydated and dissolved by the greater number of the acids. The sulphuric acid, when concentrated, requires the assistance of heat, and sulphureous acid is disengaged; when diluted, the oxydation and solution of the metal go on much more rapidly, the acid, by a disposing affinity, enabling it to decompose the water, and hydrogen gas being of course disengaged. The solution by evaporation affords crystals; the salt has a styptic taste, is soluble in 3 parts of water at the temperature of 60° , and undergoes the watery fusion when heated. Sulphat of zinc is the white vitriol of commerce. It is prepared, on a large scale, by roasting, and exposing to air and moisture, an ore containing a sulphuret of the metal; the

the sulphur absorbs oxygen, and is converted into sulphuric acid, which combines with the oxyd of zinc: the salt is extracted by lixiviation, and the solution is evaporated to dryness.

Nitric acid acts upon zinc with great violence. Nitrat of zinc is obtained by evaporation: its crystals are deliquescent, are decomposed by heat, and detonate when thrown on burning fuel. Mariatic acid likewise dissolves zinc with rapidity, the metal being oxydated at the expence of the water. The solution does not crystallize, and, when evaporated to dryness, is decomposed. Phosphoric and fluoric acids oxydate and dissolve it more slowly; water saturated with carbonic acid likewise dissolves a portion of it; boracic acid has little action on it. The alkalis and several of the earths throw down a white or yellowish oxyd from all these solutions. The metal is dissolved in inconsiderable proportion by the fixed alkalis; it likewise decomposes several neutral salts.

As zinc has so strong an attraction to oxygen, it precipitates the greater number of the metals from their acid solutions.

Though

Though zinc in its metallic state is found in nature combined with sulphur, yet the combination cannot be effected by art, owing partly to the volatilisation or oxydation of the zinc at the temperature that may be necessary for their union. The oxyds of zinc, however, combine with sulphur. The combination of the metal with phosphorus can be effected; a compound of a white colour, somewhat malleable, and having the metallic lustre, is formed. It seems also to be capable of combining with carbon, as a small quantity of carbonaceous matter is deposited during the solution of the metal usually met with, in any of the acids.

Zinc combines with a number of other metals. The most valuable alloys are those which it forms with copper; these are generally made by cementation; copper, granulated or beat into plates, being exposed to heat with a mixture of charcoal and calamine or native oxyd of zinc. Different compound metals are formed from different proportions of the zinc and copper; as brass, pinchbeck, tombac, and prince's metal. These are more fusible than copper, so that they can be more easily cast; they are less liable to tarnish, and they possess

less considerable ductility and malleability. This colour is lighter according as the proportion of zinc is augmented.

Sect. X. — — BISMUTH.

THIS metal is of a yellowish white colour, which tarnishes and becomes iridescent. Its lustre is 3.2. ; its hardness 6. ; texture foliated ; specific gravity 9.822. It possesses scarcely any ductility or malleability.

Bismuth is found native, sometimes disseminated, sometimes crystallized. The native oxyd is met with in the form of a powder, of a yellow or green colour, covering the surface, or diffused through the substance, of other ores, and sometimes likewise crystallized. It is also found mineralised by sulphur, both crystallized and amorphous, having the metallic lustre, without transparency, and with a considerable degree of hardness. From

its easy fusibility, this metal is easily extracted from the ores in which it is contained.

Bismuth is, next to tin, the most fusible of the metals, melting at about 460° . By a more intense heat, it is volatilised. If when melted it be exposed to the atmospheric air, its surface is soon covered with an imperfect oxyd: if exposed to a stronger heat, it burns with a weak blue flame, and emits vapours, which condense into a yellow powder, which is the more perfect oxyd. Either of these oxyds is easily vitrified.

Sulphuric acid, when boiled on bismuth, oxydates, and dissolves a part of it; sulphat of bismuth may be obtained in small deliquescent crystals. Bismuth is dissolved by nitric acid with great rapidity; dense vapours, consisting of a mixture of nitrous gas and nitrous acid are disengaged, and a solution of the metal is obtained, which, by evaporation, affords crystals. These are permanent in the air, and detonate slightly when heated. The solution of the metal in the acid is decomposed by the affusion of water, and a very white oxyd is precipitated. Muriatic acid scarcely acts upon bismuth, but combines with its oxyds.

oxyds. The muriat of bismuth can be distilled by heat, when it forms a thick soft mass. All these solutions are decomposed by the alkalis and several of the earths: the fixed alkalis, by digesting on the oxyds of this metal, dissolve a small portion of them.

Bismuth combines with sulphur by fusion, and forms a compound of a grey colour, having the metallic lustre. When melted, and allowed to cool slowly, it concretes into a crystalline mass. Both the metal and its oxyds unite with sulphurated hydrogen, and form a compound of a black colour. This renders the use of the white oxyd of bismuth as a pigment or a cosmetic inconvenient. This combination has likewise been used as a sympathetic ink, letters being traced with any of the solutions of bismuth, and exposed to the vapour arising from the solution of sulphuret of potash.

This metal can scarcely be combined with phosphorus, and it seems to have no attraction to carbon.

Bismuth

Bismuth is capable of combining with the greater number of the metals, but few of its alloys are applied to any use. With a large proportion of tin, it forms compounds very fusible; 5 parts of bismuth, 3 of tin, and 2 of lead, make an alloy that melts at the heat of boiling water.

Sect. XI. — — ANTIMONY,

THE name Antimony was first given to a certain mineral of a dark grey colour, shining appearance and striated texture. It was afterwards discovered to be a combination of sulphur and a peculiar metal. It is to this metal that the name Antimony is appropriated; the other is the native Sulphuret of antimony, the Crude antimony of commerce.

Antimony is of a white colour, liable to to be tarnished slightly on exposure to the air. Its texture is plated; lustre 3.; hardness 6.5.;
it

it is extremely brittle; its specific gravity is 6.702.

Antimony has been found native, alloyed with a small portion of arsenic; it has likewise occurred in the state of oxyd. The most abundant ore of it is that in which it is combined with sulphur. Its colour is bluish, or steel grey, of a metallic lustre, and often beautifully variegated. Its texture is compact, foliated, and striated. The striated is found both crystallized, massive, and disseminated; the others are always amorphous. The Plumose antimonial ore is the metal mineralised by sulphur and arsenic. The Red antimonial ore, which is rare, is supposed to contain sulphurated hydrogen as the mineraliser. Native muriat of antimony has likewise been discovered in slender crystals, of a white colour and metallic lustre.

Of these ores, the sulphuret of antimony only is wrought. It is fused to free it from the earthy matter with which it is mixed. In order to obtain the antimony, it is further roasted to expel the sulphur; and the metal being slightly oxydated, is reduced by heating it with charcoal powder, or rather with the common black flux.

Antimony

Antimony melts at about 810° of Fahrenheit: at a white heat in close vessels, it rises unchanged. When heated in contact with the air, it is changed into a grey powder, which is an imperfect oxyd. If this is exposed to a stronger heat, it sublimes, receiving at the same time more oxygen, and condensing in the form of slender white needles. The same oxyd is obtained by exposing the antimony at once to a strong heat. It is still, however, not saturated with oxygen, a more perfect oxyd, perfectly white, being obtained by exposing the metal to the heat of ignition, with two parts of nitrat of potash.

Sulphuric acid boiled upon antimony is in part decomposed, the oxyd formed combines with the remaining acid, and forms a salt, which, though soluble in water, cannot be crystallized.

Nitric acid oxydates and dissolves it in the cold, the solution affording, by evaporation, a salt, which is deliquescent, and decomposed by heat.

Muriatic acid scarcely acts upon the metal, and it even dissolves its oxyds slowly. The oxygenated muriatic or nitro-muriatic dissolves it with
more

more facility. The solution, after evaporation of the superfluous water, may be distilled by the application of heat; it comes over of a thick consistence, or forming a concrete, which melts on the application of heat. It is the Butter of antimony of the older chemists, which was prepared by various indirect modes of combining the perfect oxyd of antimony with muriatic acid; it is highly corrosive, liquefies on exposure to the air, and forms a transparent solution by the absorption of water, but is decomposed by the direct affusion of water, a white oxyd being precipitated.

The greater part of the other acids, though unable to dissolve antimony, are capable of combining with its oxyds. The only compound of this kind that is applied to use, is the tartarite of antimony; the preparation of which is to be afterwards noticed.

Antimony combines readily with sulphur by fusion, and forms a compound similar to the native sulphuret. This native compound has been more operated on by the chemists than the pure metal, and there are some preparations of it which require to be noticed.

When

When native fulphuret of antimony is exposed to heat, sulphureous fumes are disengaged, and when these cease, a grey powder remains, which is an imperfect oxyd of the metal, still combined with a small proportion of oxygen. If this powder be exposed to an intense heat, it is vitrified, and forms the *glass of antimony*.

The metal is likewise oxydated by deflagrating equal parts of the native fulphuret and of nitrat of potash, the sulphur being converted into sulphuric or sulphureous acid, and the metal into an imperfect oxyd, which, from its yellowish brown colour, was termed the *Saffron of Metals*: when the nitre is deflagrated, not with the fulphuret of antimony in its natural state, but after the sulphur has been almost entirely expelled from it by heat, the metal is more highly oxydated, and forms the *white oxyd prepared by nitre*.

When fulphuret of antimony is fused with an alkali, or when an alkaline solution is boiled upon it, the metal is slightly oxydated, and the oxyd is dissolved by the alkaline fulphuret. If the solution is strained while hot, a red powder is deposited, formerly termed *Kermes Mineral*, which is an
hydrogenated

hydrogenated hydro-sulphuret of antimony. If an acid is added to the solution, it combines with the alkali, and throws down a red precipitate, the precipitated sulphur of antimony, similar to the former, and differing from it only in containing a larger proportion of sulphur.

The last proportion of sulphuret of antimony is that obtained by exposing it to heat with powdered shavings of bones or horns, till the sulphur of the one is expelled, and the animal matter of the other destroyed. It is further subjected to a stronger heat in a covered crucible, by which the antimony is more completely oxydated, and combined with the phosphat of lime.

Antimony combines with phosphorus; the compound has the metallic lustre, and a lamellated fracture.

Antimony combines with nearly all the metals. The principal alloy of it which is applied to any use, is that of which printing types are made. It consists of 80 parts of lead, and from 15 to 25 of antimony, with frequently small proportions of bismuth and zinc.

SECT. XII. — — NICKEL.

It is difficult to obtain Nickel free from other metallic mixtures. When in its purest state, it is of a white colour with a shade of red ; lustre 3. ; hardness 8. ; its fracture is compact, and it possesses a degree of malleability ; its specific gravity varies, according to its more perfect fusion, from 7000 to 9000. When in its greatest degree of purity, it is attracted by the magnet, and is likewise capable of being rendered magnetical.

Nickel has been found native, alloyed with iron. Its oxyd also occurs native, generally efflorescent on other nickel ores, sometimes indurated, and even crystallized. Mineralised by acid of arsenic, it is found in amorphous masses of a pale grey colour, without lustre or transparency. The most abundant ore is that termed Kupfernickel, which is a compound of nickel and arsenic, with sulphuret of iron, and sometimes cobalt or copper. It is of a copper colour, inclining to yellow or grey ;

grey; its lustre metallic, and its hardness such that it is with difficulty scratched by the knife. To obtain the nickel pure from this last ore, it is roasted, to drive off the sulphur and arsenic, and the oxyd is reduced by fusing it with a mixture of black flux and sea salt. It is still combined with arsenic, cobalt, and iron; to free it from which, it is repeatedly oxydated and reduced, though it is extremely difficult to obtain it perfectly pure.

Nickel is nearly as infusible as crude iron, and is more difficult of oxydation. It suffers this change, however, by exposing it for some time to heat with the access of air, and more completely by heating it with nitrat of potash. This oxyd is of a green colour,

Sulphuric acid, assisted by heat, oxydates and dissolves this metal, the solution affording, by evaporation, green crystals. Nitric acid dissolves it, and affords the same coloured crystals, of a rhomboidal form. Muriatic acid, when heated on the metal, likewise takes up part of it, the solution affording, by evaporation, crystals, similar in colour and form to those of the nitrat. All these solutions are decomposed by the alkalis. Potash and soda

soda throw down a green, ammonia a blue precipitate.

Nickel combines with sulphur by fusion. The compound has a yellow colour with some brilliancy—is brittle and hard. It is dissolved by the alkaline sulphurets. With phosphorus, it forms a compound, of a white colour and moderate fusibility. It combines with a number of the other metals, but none of its alloys have been applied to use. Its oxyds give a hyacinthine colour to glass.

Sect. XIII. — — COBALT.

THIS metal, when pure, is of a steel-grey colour with a tinge of red; lustre 3.; texture compact; hardness 8.; specific gravity 7.811. When in the purest state in which it can be obtained, it is obedient to the magnet,

Cobalt is found alloyed with arsenic, with or without iron or nickel; the Grey cobalt ore is of
this

this kind. The White cobalt ore is the metal mineralised by sulphur, with or without arsenic or iron. In the Red cobalt ore, it is mineralised by the arsenical acid. The native oxyd likewise occurs, generally in a powdery form, of a black, brown, or yellow colour. All these ores are easily discovered by their communicating a rich blue colour to glasses, and by their solution in acids, forming sympathetic inks, lines traced with them becoming green on exposure to heat.

In the large way, the cobalt ores are roasted, to expel the sulphur and arsenic, and the metal is obtained oxydated; in which state it is used in the arts. It forms the Zaffre of commerce, which, when fused with siliceous earth, forms Smalt.—Cobalt may be obtained by mixing zaffre with 3 times its weight of black flux and a small quantity of sea salt, and exposing it to a very strong heat for some hours—a metallic button will be found at the bottom of the crucible.

Cobalt requires a very intense heat for its fusion, nearly the same as that necessary to melt cast iron. When heated in contact with the air, it oxydates at a temperature lower than that at which

which it melts. Its oxyd is of a deep blue colour, and it gives a similar colour to glass.

Sulphuric acid, boiled upon cobalt, dissolves a portion of it; the solution affords, by evaporation, crystals of the same colour. Nitric acid dissolves it, and the solution yields reddish deliquescent crystals. The muriatic acid, even when assisted by heat, acts very feebly on cobalt; the oxygenated muriatic, or nitro-muriatic, dissolves it with facility. The solution of muriat of cobalt changes its colour to a green when heated, and from this property is used as a sympathetic ink, letters traced with it upon paper being invisible until the paper is heated. It is prepared by dissolving 1 part of cobalt, or $1\frac{1}{2}$ of zaffre, in 3 parts of diluted nitric acid, with the assistance of a moderate heat, diluting the solution with 24 parts of water, and adding one part of muriat of soda.

Ammonia dissolves the oxyd of cobalt, and acquires a deep red colour. In this combination it has been supposed that the cobalt, or at least a portion of it, is not merely an oxyd, but exists in the state of an acid.

Cobalt

Cobalt combines with sulphur by fusion, but only in inconsiderable quantity. The alkaline sulphurets dissolve it. It unites with phosphorus, forming a brittle and fusible compound. It unites with all the metals, silver, mercury, lead, and bismuth excepted; but none of its alloys are applied to any use.

Seçt. XIV. — — MANGANESE.

MANGANESE is of a greyish white colour; lustre 3. which tarnishes quickly on exposure to the air; hardness 8.; specific gravity 6.850. It is very universally diffused, being found not only in the earth in various forms, but in the ashes of many vegetable products.

The native oxyd of manganese is its most abundant ore; and from the various degrees of oxydation in which it exists, and its mixture with foreign substances is found in different states, with respect to colour, texture, form, and other properties. It occurs both amorphous and crystallized; has an earthy

earthy texture, and generally a brownish or blueish black colour. Sometimes the native oxyd is combined with carbonic acid, forming two varieties of the native carbonat, the white and the red: these likewise generally contain a large portion of siliceous earth and of oxyd of iron.

It is extremely difficult to reduce the oxyds of manganese to the metallic state, and still more so to fuse it into a metallic button. It can hardly even be obtained but in small globules. When these are exposed to the air, especially to moist air, their colour tarnishes, they split and fall into a black powder. This change is ascribed to oxydation of the metal; yet it has been affirmed, that there are other specimens of it which remain permanent in the air. By heating it, however, in contact with the air, it is oxydated at a temperature very far below that which is necessary to melt it.

In these oxydations, the metal absorbs different quantities of oxygen, and the product varies in colour and other properties. There seem, however, to be, strictly speaking, only two oxyds of manganese; one, which is precipitated from its solution

solution in acids by alkalis, is white, and which, according to the experiments of Bergman, consists of 20 of oxygen with 80 of metal; the other, the black, formed by oxydation of the metal by heat, or by long exposure of the white oxyd to heat, and which contains 25 parts of oxygen in the 100. From the intermixture of these, oxyds are obtained of every intermediate colour. The attraction of the metal to the oxygen in the first state of oxydation is extremely strong, superior, perhaps, to that of any other metal; but the additional quantity combined with the white oxyd to constitute the black, is retained by so weak an attraction, that it escapes at the temperature of ignition.

These two oxyds are differently affected by the acids. If to any of the perfect acids, as the sulphuric or nitric, the black oxyd be added, it remains undissolved; but if any inflammable matter be added, the solution commences, as this matter abstracts part of the oxygen of the acid, and this again part of the oxygen of the oxyd, by which it is rendered soluble in the acid. In the same manner, the black oxyd is soluble in the sulphureous or nitrous acid, and the white oxyd in the

fulphuric or nitric. The black is likewise capable of combining with the muriatic acid, as part of its oxygen is abstracted by one portion of the acid, and oxygenated muriatic acid formed. These facts shew, that metallic oxyds must be in a certain state of oxydation to be soluble in acids, and that an excess of oxygen may render them insoluble.

The combination of the white oxyd with fulphuric acid, or the sulphat of manganese, is soluble in water, and easily crystallizable. The nitrat of manganese cannot be obtained in a crystalline form; and the mass, to which it is reduced by evaporation, is deliquescent. The muriat likewise forms, by evaporation, a soft deliquescent mass. These compounds are decomposed by the alkalis, and the white oxyd is precipitated. The fixed alkalis are likewise capable of combining with the black oxyd. This combination is obtained by exposing to a strong heat one part of it with two parts of potash or soda. When the compound is dissolved in water, the solution has first a green colour, then a purple, and lastly a red; and by the addition of a small quantity of nitric acid, it is rendered colourless—changes owing to variations in the degree of oxydation of the oxyd.

Manganese

Manganese appears to be incapable of combining with sulphur. Phosphorus combines with it, and forms a compound of a white colour and metallic lustre, brittle and fusible. To carbon, the pure metal has likewise an attraction, and it is indeed difficult to obtain it uncombined with it. From the difficulty of obtaining pure manganese, and its extreme infusibility, it is not easy to combine it with the other metals, and few of its alloys are known. Iron seems to have a strong attraction to it, as they are often found combined in nature.

The oxyd of manganese is capable of uniting by fusion with the earths, and in a large quantity it gives a violet colour to glass. The use of it in smaller quantity is of great use in the art of glass-making, to render the glass more free from colour than it would otherwise be; this it does by parting with its oxygen, and thus destroying any inflammable matter in the ingredients, and by completely oxydating the oxyd of iron, while it is itself changed to the white oxyd. In pottery it is used to give the ware a black colour.

See.

 Sect. XV. — — ARSENIC.

ARSENIC is a metal of a bluish colour, with the metallic lustre, which quickly tarnishes on exposure to the air, its colour becoming grey, or even black. Its texture is foliated; it is very brittle, without much hardness; its specific gravity is stated variously, — by Bergman at 8310, by Bliffon at 5763.

This metal is sometimes found native, alloyed with iron, silver, or gold. In the state of oxyd, it is met with in a powdery form, in fragments more or less indurated, and even crystallized. Combined with sulphur, it forms two ores, Orpiment and Realgar—the former being of a yellow, the latter of a red colour; the orpiment contains much more arsenic than the other. The arsenical ore, termed Mispickel, is a species of pyrites, or compound of iron and sulphur, to which arsenic is joined.

Arsenic

Arsenic, in the usual mode of extracting it from its ores, is always obtained in the state of oxyd; the ore is roasted, and the oxyd of arsenic being volatile, passes off in fumes, which condense in the chimney of the furnace into a white powder, commonly known by the name of White arsenic. When this oxyd is made into a paste with common soap, and exposed to a moderate heat, it is reduced, and the metal, being volatile, is sublimed.

This great degree of volatility distinguishes arsenic from the other metals: it sublimes in close vessels when heated to 356 of Fahrenheit. When heated with the access of atmospheric air, it is oxydated with facility; and when the temperature is that of ignition, it burns with a blue flame, and emits fumes of a garlic smell: these consist of the white oxyd, which is easily condensed. This oxyd is volatilised with facility: it has a sharp caustic taste, and is soluble in water: its solution in boiling water even affords crystals on cooling—properties which shew that it is nearly of a saline nature. By a further oxygenation, it is completely acidified.

The

The imperfect oxyd of arsenic is not dissolved but in very minute proportion by sulphuric acid. Nitric acid communicates to it a larger proportion of oxygen, and acidifies it, so that a nitrat of arsenic can scarcely be obtained. Muriatic acid dissolves it abundantly, especially when assisted by heat; the oxygenated muriatic acid dissolves it with still more facility; and if the filings of the metal be dropt into this acid in its gaseous state, they are inflamed. There seem to be two combinations of oxyd of arsenic with muriatic acid; one, in which the metal is more oxydated than in the other. The Oxygenated Muriat of Arsenic, as it has been termed, is concrete, of a soft consistence, emits suffocating vapours, imbibes moisture from the atmosphere, and is decomposed by the affusion of water.

Oxyd of arsenic is capable of combining with the fixed alkalis by fusion; it is also dissolved by their watery solutions when assisted by heat.— This saturated solution is thick and tenaceous, and emits fumes of a disagreeable odour, supposed by some to be arseniated hydrogen. Ammonia and lime water, by digestion on this oxyd, are likewise able to dissolve a portion of it.

Acid

Acid of arsenic is obtained by distilling nitric acid from the white oxyd ; a large quantity of nitrous gas is discharged, and the acid of arsenic remains in a concrete form. Exposed to the heat of ignition, it is fused without decomposition ; but by a more intense heat, part of its oxygen is expelled. It is soluble in twice its weight of water, deliquesces, reddens the vegetable colours, and has a caustic taste.

This acid is capable of combining with the alkalis. Saturated with potash, it forms a salt which, by evaporation of its solution, affords rhomboidal crystals : with soda, it affords a salt which concretes in octohedral crystals, that effloresce on exposure to the air : with ammonia, it forms a compound, likewise capable of crystallization, and which is easily decomposed by heat. It combines with a number of the earths and metallic oxyds ; but these combinations are uninteresting, and have been little examined.

Arsenic combines with sulphur, and its oxyd and acid are decomposed by the inflammable substance. The metal, by fusion and sublimation, unites with the sulphur, forming, according to the proportions

proportions, compounds of a red or yellow colour, similar to the native orpiment and realgar. When the oxyd or acid is heated with sulphur, the sulphur attracts its oxygen, and sulphureous acid is disengaged. The alkaline sulphurets are likewise capable of dissolving arsenic and its oxyds; and if to these solutions an acid be added, a compound of oxyd of arsenic and sulphurated hydrogen is precipitated.

Phosphorus combines with arsenic, and forms a compound, of a black colour and metallic lustre, which is oxydated by exposure to the air.

Arsenic combines with almost all the metals. It has in general been observed, that it renders the ductile metals brittle, and those that are refractory in the fire more fusible. Of these alloys, that with copper is almost the only one that is applied to any use. It is of a white colour, flexible and malleable, admits of a fine polish, and is frequently used plated with silver.

Oxyd of arsenic throws down from a solution of fulphat of copper a precipitate of a fine green colour; it is the arsenical oxyd of copper, and is
used

used as a paint. This precipitation is one test by which the presence of arsenic may be detected; others are, the fumes and garlic odour which it diffuses when put upon a hot iron,—its effects in whitening a copperplate when mixed with the black flux and exposed to heat,—or its reduction and sublimation by a very moderate heat, when previously mixed with three times its weight of this flux.

SECT. XVI. — — MOLYBDENA.

THE native combination of the oxyd or acid of this metal with sulphur is so similar, in several of its properties, to plumbago, that they were long confounded as varieties of the same substance. Scheele shewed, that a peculiar metallic acid might be obtained from it; and latter chemists have succeeded in reducing this acid to the metallic state. This native sulphuret, which is the only ore of the metal, is of a light grey colour, its surface is smooth and unctuous, its texture lami-

nated, and so soft that it soils the fingers. From its great infusibility, and the strong attraction between its principles, the pure metal cannot be directly obtained from it. If exposed to a strong heat in contact with the air, sulphureous fumes are disengaged, and the oxyd of the metal remains; or if 30 parts of nitric acid be distilled from it, it is combined with as much oxygen as to form an acid, which remains in a concrete state.

Few chemists have succeeded in reducing the oxyd or acid of Molybdena, owing to its great infusibility. It has been obtained only in small metallic globules. Its colour is white, with a yellow shade; its lustre inconsiderable; its specific gravity is from 6.000 to 7.500. It is one of the most infusible of the metals.

Molybdena is capable of various degrees of oxydation, not less than four, according to the experiments of Mr. Hatchet: the lowest constitutes a black oxyd; the second, a blue; the third, a green; and the fourth produces a concrete of a yellowish white colour, having acid properties.

In

In these different states, the metal has not a very strong attraction to oxygen; in the acid compound especially, it is so weak that mere exposure to light, passing through it a current of hydrogen, or digesting it with any of the metals, changes its colour to a blue by partially de-oxydating it.

The molybdic acid possesses all the general acid properties. It melts and is decomposed by heat; it is soluble in about 750 times its weight of water; it is also soluble in the sulphuric and muriatic acids. It combines with the alkalis and earths, forming salts termed Molybdats; and it oxydates several of the acids. These combinations have not been particularly examined.

Molybdena is capable of combining with a number of the metals by fusion; but its alloys have not been applied to any use.

See.

SECT. XVII. — — TUNGSTEN.

UNDER the name of Tungsten, a substance was known to mineralogists, which was after some time discovered to consist of lime, combined with a peculiar metallic oxyd or acid. The same metallic principle was afterwards discovered, united with iron and manganese, in another mineral termed Wolfram. These two substances, therefore, are ores of one metal. The first, the tungstat of lime, occurs massive, disseminated, and crystallized, possessing a moderate share of lustre and hardness: it contains from 12 to 30 parts of lime in the 100. The second likewise occurs both massive and crystallized, having a metallic lustre, a foliated texture, and a considerable degree of specific gravity. It contains in the 100 from 22 to 32 parts of manganese, and 11 or 13 of oxyd of iron.

From native tungsten the metallic oxyd is extracted by digesting the mineral reduced to a fine powder

powder in 3 parts of nitric acid, when a yellow powder is deposited. This, to obtain it pure, is digested with ammonia, with which it combines, and is again precipitated by nitric acid. From wolfram it is extracted by boiling the mineral with muriatic acid, which dissolves the iron and manganese, and leaves the same yellow powder. This may be reduced to the metallic state by exposing it, made into a paste with oil and charcoal, to an intense heat for two hours. Metallic grains are thus obtained which cannot be fused into a mass of any bulk. The metal appears of a greyish colour, is exceedingly hard and brittle, and has a specific gravity equal to 6.678.

The yellow matter from which the reguline tungsten is obtained, is tasteless and insoluble in water. It combines with the alkalis and several of the earths, and has hence been considered as an acid. When freed completely from the acids employed in its preparation, it has, however, no acid property; and as there are other oxyds capable of combining with the alkalis and earths, it can perhaps be considered only as an oxyd. Neither the oxyd nor the metal has been applied to any use; but

but in its oxydated state it has been proposed as a basis for pigments, since the compounds which it forms with vegetable colouring matter have very permanent colours.

Sect. XVIII. — — URANIUM.

THIS is a peculiar metal, lately discovered by Klaproth. It exists in the mineral termed Pechblende, combined with sulphur and a portion of iron, in Chalcolithé, united with carbonic acid, — and in uranitic ochre, mixed with oxyd of iron.

The oxyd of uranium is of a lemon yellow colour; it is infusible by heat; ignition changes its colour to a brownish grey. When mixed with carbonaceous matter, and urged by an intense heat, metallic globules have been obtained. The colour of this metal is steel grey, with little lustre; its specific gravity is 6.440; it is susceptible of a fine polish, and does not tarnish on exposure to the air. By heat it affords a yellow oxyd.

Nitric

Nitric acid oxydates and dissolves this metal: sulphuric, muriatic, and other acids combine with its oxyds, and afford salts which crystallize. Its oxyd is incapable of combining with the alkalis, by which it is distinguished from that of tungsten; but it dissolves in the alkaline carbonats, and by fusion it may be combined with the earths. Both the metal and its oxyd seem capable of combining with sulphur. Its relations to the different metals are not precisely known.

SECT. XIX. TITANIUM.

THIS is likewise a newly discovered metal. It was first noticed by Mr. Macgregor as existing in the state of oxyd, mixed with iron, manganese, and filiceous earth, in a greyish black sand, found in the vale of Menachan in Cornwall, and thence named by him Menachanite; and it has since been discovered by Klaproth, in an ore named titanit, in the *sidero-titanium*, and in the red schorl of Hungary. In these it exists in the state of oxyd. This oxyd is of a red colour, and when partially

tially de-oxydated, by heating it with inflammable substances, is of a yellow or blue. It is very hard, is infusible, is soluble with the assistance of heat in diluted sulphuric, in nitric and muriatic acids, and affords gelatinous solutions, which yield crystals by spontaneous evaporation, but are decomposed by boiling. These solutions are decomposed by the alkalis. Prussiat of potash throws down a green precipitate, the Gallic acid one of a brownish red colour.

Klaproth was unable to reduce this metallic oxyd. Vauquelin, by exposing it to a strong heat with different fluxes, observed it to assume a metallic appearance; but the metal, when reduced, appeared to be volatilised. From a few metallic grains obtained, it was found to be of a red yellow colour, and crystalline texture; brittle, and extremely refractory. It has not been found capable of uniting with any of the other metals, iron excepted.

 Sect. XX. — — TELLURIUM.

THIS is another new metal, discovered by Muller and Klaproth. It exists in an ore of gold, which was formerly named *aurum problematicum*, and in several other gold ores, from which it is easily extracted. Its colour is white or greyish, with a considerable share of lustre; its texture is lamellated; it is brittle; is much disposed to assume a crystalline appearance on its surface; its specific gravity is 6.115. It is one of the most fusible metals, melting as easily as lead: it is also easily volatilised. When much heated, it burns with a blue flame, and is oxydated.

The oxyd of tellurium is white, but becomes yellow on exposure to heat, and by a moderate heat is volatilised. It is very easily reduced by heating it with inflammable substances.

Tellurium is oxydated and dissolved by the nitric and nitro-muriatic acids. The saturated solu-

tion in the latter is decomposed by water, which precipitates the oxyd. The metal is likewise soluble in fulphuric acid; the solution acquires a fine red colour, which is lost, either by heating it or adding water.

The alkalis throw down a white oxyd from these solutions; the oxyd is redissolved by an excess of alkali. The metal is precipitated by iron, zinc, tin, and antimony. It unites with several of the other metals, and amalgamates with mercury.

Sect. XXI. — — *CHROME.*

THIS metal has been lately discovered by Vauquelin. He found it to exist in a species of lead ore, the red lead of Siberia, and which, he has shewn, consists of oxyd of lead, combined with a peculiar metallic acid, which can be reduced to the reguline state. It is named Chrome from its property of communicating brilliant colours to the greater number of its combinations. Chromat of iron has likewise since been discovered; and the
oxyd

oxyd or acid of the metal, it has been proved by Vauquelin, serves as the colouring matter of the emerald. It probably exists in other gems.

The acid of chrome, extracted from any of its native combinations, is of a beautiful ruby red colour, and in crystals of a prismatic figure. These are soluble in water, and have a sharp metallic taste. It combines with the alkalis, and forms crystallizable salts of a golden yellow colour; it also unites with the different metals, and forms compounds distinguished by the splendour of their colours. Fused with phosphoric acid, or with borat of soda, vitreous globules are obtained, of an emerald green colour.

Amongst the acids, the muriatic has the most remarkable action on it. When heated with it, it attracts part of its oxygen, a quantity of oxygenated muriatic acid is formed, and the solution assumes a beautiful deep green colour, owing to the chromic acid having passed to the state of an oxyd, which is dissolved by the muriatic acid. The same green oxyd is obtained by heating the acid by the blow-pipe, in contact with charcoal.

Vauquelin

Vauquelin reduced this acid by exposing it to a strong heat completely bedded in charcoal powder: a metallic mass inferior in weight to the acid is obtained. It is of a greyish colour, with brilliancy, very brittle, is fused with difficulty, fixed in the fire, and in cooling disposed to crystallize. Heated in contact with the air, its surface is covered with a green oxyd. The nitric acid oxydates it; but so sparingly, that in order to produce this change, it is necessary to distil to dryness, five or six times successively, 20 parts of the concentrated acid from one of the metal.

CHAP.

CHAP. VI.

EARTHS:

EARTHS IN GENERAL.

IN common language, the term Earth is applied to any substance which is dry, opaque, insipid, of a loose texture, infusible, and of sparing solubility in water. In chemical language, the meaning of the term is more appropriate. It is confined to a few simple substances, obtained as ultimate principles in the analysis of the various fossils, not metallic, afforded by nature. They are distinguished by the following properties: They are unflammable, and destitute of the metallic splendour and opacity, and are incapable of acquiring these properties; their specific gravity is less than that of 5 to 1; they are sparingly soluble in water; are
extremely

extremely infusible; are capable of combining with acids when they form neutral salts, and they are likewise disposed to unite with the fixed alkalis, with sulphur and phosphorus, with metallic oxyds, and with each other, either by fusion or solution in water.

Of these distinctive properties, the most characteristic is the want of inflammability. From this property, and from their possessing a number of other properties, similar to those of the metallic oxyds, it has been concluded that they are metals already saturated with oxygen, and exerting to that principle a strong attraction. Various attempts have, therefore, been made to reduce them, but without success. Though the earths are incapable of combining with oxygen, so as to exhibit the phenomena of combustion, it has lately been affirmed by Von Humboldt, that several of them, when pure and moistened with water, absorb it with avidity; but other chemists have denied that any such absorption can be detected by experiment.

The earths are the most infusible of any class of bodies. Some of them have been fused, but only

only by a very intense heat ; and others have resisted every mean to effect their fusion. When mixed, however, with each other, they become more fusible, and fuse at a temperature which would be unable to melt them separately. This is owing to the chemical attraction which they exert to each other, which tends to unite them, and form a more fusible compound.

With respect to solubility in water, there is none perhaps absolutely insoluble, but the greater number require a very large quantity for solution.

All the pure earths are capable of combining with more or fewer of the acids. The siliceous is dissolved only by the fluoric ; the others are more extensive in their power of combination. The compounds which they form are neutral salts, and are denominated as such according to the principles of the new nomenclature. Many of these compounds retain the insolubility of their bases in water, others are as soluble as the alkaline neutral salts. They are capable of crystallization. In general the force of their attraction to the acids is inferior to that of the alkalis, though to this there
are

are two striking exceptions, barytes and strontites exerting much superior attractions, and being able to decompose the great part of the salts with an alkaline base. It is more generally true, that the earths exert a stronger attraction than the metallic oxyds do to the acids. The solutions of the earths are not precipitated by the prussiate of potash—a property by which they are distinguished from the metals. Barytes, however, is an exception, as it suffers a precipitation of this kind.

When the earths are fused with each other, with many of the metallic oxyds, or with the alkalis, they form glasses more or less transparent, and coloured.

The earths are likewise capable of uniting with the alkalis, and with each other, in the humid way. This fact, which had been known with respect to the alkalis, and, to a certain extent, with respect to the earths, has been more lately established by Morveau. If mixtures of different earths are boiled together in water, they unite, and change their qualities; or if solutions of two earths in the same solvent are mixed together, a precipitate

state is in many cases formed, from the two earths, by their superior attraction, combining together; and this combination is frequently so intimate, that it resists the action of an acid capable of dissolving either of the earths in its pure state.

Several of the earths are distinguished by possessing certain properties which characterise the alkalis. Barytes, strontites, and lime, are considerably soluble in water, have an acrid penetrating taste, act as caustics on animal matter, change the vegetable colours to a green, combine with oils so as to form soap, are capable of dissolving siliceous earth, and exert an attraction to the acids even stronger than that of the alkalis. These have therefore been termed Alkaline earths; and Vauquelin has proposed, that these three substances should be entirely transferred from the order of earths to that of alkalis,—a method of arrangement which has already been adopted by several chemists. Its propriety, however, is very questionable. Of the above properties, the greater number,—such as changing the vegetable colours to a green, combining with oil and with acids, uniting with earths in the humid way, and

with filex by fusion,—belong not only to several substances still left in the class of earths, as magnesia and argil, but even to a number of metallic oxyds: they cannot therefore be termed Alkaline properties. The three earths above enumerated differ from the alkalis, and agree with the other earths, in their infusibility by fire, in forming with carbonic acid insoluble compounds, and in being insoluble in alkohol. With the latter, therefore, they form one order, amongst the substances composing which there is a gradual transition in activity from barytic to siliceous earth.

There are at present known ten simple earths, filex, argil, magnesia, lime, barytes, strontites, zircon, glucine, augustine, and yttria. The four last have been only lately discovered, and in very inconsiderable quantity.

Of these earths mixed or combined with each other, or with the acids, are formed the immense variety of fossils existing in nature. The study and arrangement of these substances forms the branch of knowledge termed Lithology, and conjoined with the study of the metals and their
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ores, the more comprehensive science of Mineralogy.

The object of lithology is to distinguish and arrange the various substances of which it treats. It is obvious that this must be done from their properties, or from their chemical composition; and both these methods are employed by modern mineralogists. As many genera are formed as there are simple earths: every compound fossil is referred to the genus derived from the simple earth which predominates in its composition, or which gives it the peculiar characters of that genus: species are formed from certain assemblages of properties in these substances; and varieties or individuals are characterised by peculiar properties, either external or internal, colour, form, texture, density, hardness, transparency, fusibility, and relations to certain chemical agents. In a chemical work, the different genera of earthy fossils may thus be considered after the history of each of the simple earths.

Sect.

Sect. I. — SILEX.

SILEX, or siliceous earth, is the principal constituent part of a very great number of the compound earths and stones, and the sand of rivers and of the sea shore chiefly consists of it. It exists in greatest purity in rock crystal, which contains 93 parts of it in the 100. When it is freed from every impurity, it exists in the form of a light white powder, insipid and inodorous, and infusible in the fire. It has been considered as insoluble in water, but it appears, when in a state of extreme division, to be soluble in minute quantity, and it is found in nature in such a state of solution. It is peculiarly distinguished from every other earth, by its not being acted on by any of the acids, the fluoric excepted. In the way of fusion, however, it seems to be capable of combining with the boracic and phosphoric acids.

The

The principal chemical combination which it forms is that with the fixed alkalis. It unites with them in different proportions, and forms compounds possessing different properties.

When one part of flint is fused with four parts of the sub-carbonat of potash, the earth and the alkali unite, and a vitrified mass is obtained. It has a sharp caustic taste, deliquesces on exposure to the air, and is soluble in water. The solution forms what was termed *liquor silicum*, or liquor of flints. A similar compound is obtained by using soda, or by boiling the solution of either alkali upon the earth. If to any of these liquors an acid be added, it combines with the alkali, the flint is precipitated; and it is by this process that it is obtained pure.

When the earth is fused with a smaller proportion of alkali, a compound is formed, possessing considerable hardness, and great transparency, which is permanent in the air, and insoluble in water. This is the well-known compound, glass, one of the most valuable products of art.

The

The essential component parts of glass are, potash or soda, and siliceous earth, in the proportion of one part or one and a half of the former to two of the latter. Sand and the potash, or barilla, of commerce are generally used. After the ingredients are intimately mixed together, they are exposed to a strong heat, by which a semi-vitrified mass, termed the Frit, is formed. This is afterwards melted, and kept in fusion for some time, by which the vitrification is completed and the glass is formed. Its transparency and other estimable qualities are greater as the materials have been pure, and according to their proportions. The less alkali is present, the more heat is requisite for its vitrification; but the glass is more hard, and less liable to be altered by exposure to air or moisture. The black oxyd of manganese and nitrat of potash is used in its composition to render it more colourless, and oxyd of lead is added to increase its density, and to render it more ductile and susceptible of a finer polish,

When glass is in the state of fusion, it has a great degree of tenacity and ductility, and is thus capable of being wrought into any shape. Tho' ductile at a high temperature, it is extremely brittle

brittle when cold especially if it has been hastily cooled. This extreme brittleness is, to a certain degree, remedied by the process of annealing, which is merely cooling the glass very slowly, after it has been formed into vessels.

A branch of the art of glass-making is that of imitating the gems, or the making of what are termed Pastes. The basis of these is a very hard and pure crystal, obtained by melting pounded quartz with an alkali, with the addition of borax, nitre, and oxyd of lead, different metallic oxyds being likewise added to imitate the colour of the gems. When glass is fused with a large quantity of oxyd of tin, it becomes white and opaque, forming what is termed Enamel.

It remains to notice the various fossils existing in nature, of which silica is the principal constituent part. Their general characters are transparency, lustre, and a degree of hardness, such that they strike fire with steel; but there are many of them which do not possess these qualities.

The

The gems, from their lustre and hardness, have been ranked as siliceous fossils, and the greater number of them contain this earth as one of their constituent principles. Their analysis has not, however, been performed with that degree of accuracy necessary to render certain the results that have been afforded.

Rock crystal is the first pure siliceous fossil. It consists, according to the analysis of it by Bergman, of 93 parts of siliceous earth, 6 of argil, and 1 of lime. It is always crystallized, usually in hexangular prisms, surmounted with hexagonal pyramids, transparent, generally colourless, but not unfrequently likewise of various shades, from the presence of iron, when it forms the false gems. It is brittle, and extremely hard; it is infusible, and is not acted on by any of the acids, the fluoric excepted: its specific gravity is 2.653.

Quartz differs from the former in wanting its transparency. It occurs both amorphous and crystallized; but its crystals have always a degree of opacity, generally milky, but not unfrequently with various shades of colour. It possesses lustre and hardness, has a specific gravity nearly

ly

ly the same as rock crystal, and is equally infusible, but decrepitates when exposed to an intense heat. Quartz is an ingredient in many compound stones.

Chalcedony is the siliceous fossil most analogous to quartz. There are several varieties of it. The common chalcedony is of a grey or brown colour, with various shades of yellow, blue, or green, in mamillated, stalactitical or spherical masses; its hardness considerable; its specific gravity from 2.606 to 2.628. It is infusible but by a stream of oxygen gas. According to Bergman, it consists of 84 parts of siliceous earth and 16 of argil, with a small portion of iron.

When chalcedony is opaque, and of a milk-white colour, it is termed Cacholong; when of a flesh-red colour, semi-transparent, and amorphous, it forms Cornelian; when stained with arborisations, Mocho stones. Some varieties acquire transparency when plunged in water: these are termed Hydrophanes, or *oculus mundi*. The Opal, a stone which exhibits glittering changeable colours, blue, red, or green, Pitchstone, Girasol, and Hyalite, are fossils of the same family.

Flint differs from chalcedony in having less lustre and transparency. It is of a greyish or yellowish colour, sometimes with veins, stripes, or dots: its fracture is conchoidal; its specific gravity from 2.58 to 2.64. It decrepitates when exposed to heat, and is softened only by the heat urged by a stream of oxygen gas. It consists of from 80 to 98 of siliceous matter, with small portions of argill, lime, and oxyd of iron. Petro-silex, chert, or hornstone, is similar to flint, but is of a coarser grain; has a splintery fracture, coarser grain, and inferior lustre, transparency, and hardness.

Jasper is a siliceous fossil, which exhibits great variety in its appearances. Its colours are white, grey, yellow, red, and green, of various shades, and intermingled with each other, variegated, spotted, or veined. It is susceptible of a high polish, and when polished has considerable splendour. In hardness, it is inferior to flint, but it still strikes fire with steel. It does not decrepitate when heated, and is very imperfectly fused, even by the heat produced by a stream of oxygen gas. The dark-coloured varieties lose a great part of their colour.—Many varieties of the jasper are formed from its colours, the nature of the variations

gations on its surface, or its mixture with quartz or other fossils. Where it is composed of alternate broad stripes or layers of different colours, straight or curved, it is termed Ribband jasper;—the variety which is found in spheroidal masses, and exhibits various colours, or shades of the same colour in concentric and alternating stripes or layers, is termed Egyptian Pebble. The Heliotropium is much allied to jasper, and differs from it in possessing rather more transparency, which is apparent towards the edges of its fragments: its colour is dark green, stained with crimson spots. It contains 68 of flint, 15 of argil, and 10 of oxyd of iron.

Under the name of Agate, several siliceous fossils are comprehended, concerning the arrangement of which authors have differed. In strict propriety, the agate does not form a distinct species, those stones which have been distinguished by this name being aggregates of others, forming a mass of different colours, semi-pellucid, and susceptible of a fine polish. Their more common constituents are quartz, chalcedony, flint, and jasper, variously intermixed, and forming a number of varieties. There is another aggregated stone composed

composed of filiceous fossils, the Pudding stone. It is a collection of rounded pebbles, cemented together by a filiceous matter intermixed with iron. It takes a fine polish, and possesses a considerable degree of hardness.

Felspar is distinguished from the preceding fossils by its fusibility in the fire. It occurs amorphous, interspersed, and crystallized; its texture is foliated; its colour is white, grey, red, and sometimes blue or green; lustre inconsiderable, and hardness moderate. Its constituent parts are silica, argil, lime, and magnesia, with frequently barytes and iron, and, according to Vauquelin, potash. Felspar is a very abundant fossil, not in its pure state, but as an ingredient in several of the aggregated stones.

What is termed the Labradore Felspar, though much less fusible than the common, has been considered as a variety of it. Its colour is grey with a shade of blue or green, but in certain positions it reflects very bright tints of blue, purple, red, or green: its transparency and hardness are nearly the same as in common felspar; its texture is foliated—it occurs amorphous. The green felspar of
Siberia

Siberia is similar to the above. Vauquelin found it to consist of 63 of filex, 17 of argil, 16 potash, 3 lime, and 1 oxyd of iron,

Zeolite.—This fossil is distinguished by two properties, forming a gelatinous solution with acids, and swelling or frothing up when heated by the blow-pipe, till it melts into a white semi-transparent enamel, which is still soluble in acids. It occurs both amorphous and crystallized; has a lustre somewhat pearly; its colour is white, with shades of yellow or red, greenish, or even blue; its texture is generally fibrous or radiated, sometimes stellated; its transparency 2.3.4.1; its hardness from 6 to 8; its specific gravity only from 2.07 to 2.21. By different analyses it is composed of from 48 to 58 parts of filex, from 22 to 31 of argil, from 8 to 14 of lime, and in general from about 16 to 22 of water,

Prehnite is similar to zeolite in lustre, texture, and swelling before the blow-pipe, but it is much harder and heavier; is of a green colour, and does not gelatinate with acids.

Staurolite occurs in semi-transparent crystals,
of

of a white colour; lustre 2.; so hard as to strike fire with steel, and brittle: specific gravity 2.355. Heated, it loses part of its weight. It consists of filix 44, argil 20, barytes 20, and water 16.

Shorl is of a black colour, without transparency; lustre 2.; hardness 10.; specific gravity from 2.92 to 3.212. It is found in masses, of an undeterminate form, or crystallized. By a strong heat it is converted into a compact black enamel. From the analysis of it by Klaproth, it is composed of filix 54, argil 25, lime 9, oxyd of iron 9, and magnesia 1. It is found in most primitive mountains, and is an ingredient in granite. The Tourmalin is a similar fossil; it differs from the shorl principally in its crystals being transparent, and its colour varying from a dark brown to a red, green, or blue.

Garnet is of a deep red colour, sometimes varying to brown, black, or violet; its hardness from 10 to 11; its lustre 2.3.; transparency 2.3.1.; specific gravity from 3.941 to 4.000. It is fusible by heat into an opaque dark grey enamel. The common red garnet consists of filix 48, argil 30, lime 11, and iron 10.

Leucite,

Leucite, or white garnet, is in small crystals, opaque, and of a white colour. According to Klaproth, it contains silica 54, argil 23, and potash from 20 to 23.

Obsidian, or Iceland Agate, has from its glossy appearance been supposed to be of volcanic origin; but this opinion is rejected, as it has been found inhering in granite. It is of a deep black colour, has a glossy lustre, with transparency equal to 1; its fracture is conchoidal; its hardness 10, and specific gravity 2.348. It consists of from 63 to 69 of silica, from 20.5 to 22 of argil, and from 9 to 13.5 of iron.

Lazulite, or *lapis lazuli*, is a stone of a rich blue colour, of an earthy fracture, opaque, having little lustre, but susceptible of a fine polish. By a strong heat, it is fused into an enamel. According to Klaproth, it consists of 46 of silica, 14.4 of argil, 28 of carbonate of lime, 65 of sulphate of lime, 3 oxyd of iron, and 2 water. Morveau has shewn, that its colour depends on a blue sulphuret of iron.

These

These are the principal siliceous fossils. *Silex* is found in various other states. It is deposited in vegetable substances, forming petrified wood, &c.; it is likewise deposited from certain springs in a stalactitical form; it has been discovered in several waters in a state of solution; and it is found in several parts of vegetables.

Sect. II. — ARGIL, or ALUMINE.

ARGIL, though abundant in nature, is not found in a pure state, and is therefore obtained from its combinations. Any quantity of the salt termed Alum, which consists of sulphuric acid united with this earth, is dissolved in 20 parts of water, and ammonia is added, which combines with the acid, and precipitates the argil. The earth is washed with water, and dried. It is perfectly white, insipid, and light, its specific gravity being 200. It is smooth and unctuous to the touch, is easily diffused through water, and with a small quantity of fluid forms an adhesive plastic mass. This, when exposed to heat, contracts much in volume :

volume: when urged by a strong heat, it acquires a very great degree of hardness, but when pure, it cannot be perfectly fused.

This earth combines with the greater number of the acids. Its compounds have in general a sweetish styptic taste.

SULPHAT of ARGIL.—With sulphuric acid, this earth forms the alum of commerce. This salt is found native, but the greater part of what is used is the produce of art. It may be formed by the combination of its principles; but the common process is to form it from what are termed alum ores, which are native combinations of sulphur and argillaceous earth, with more or less iron: these are roasted, and exposed to air and moisture; the sulphur, absorbing oxygen, is converted into sulphuric acid, which combines with the argil, and the salt is extracted from the materials by washing.

In order to cause the solution to crystallize, it is found necessary to add to it a small quantity of potash, or of urine which affords ammonia, or of

both. The effect of these additions, it was supposed, was to neutralise the excess of acid, which prevented the crystallization ; but Chaptal and Vauquelin have shewn, that they enter into the composition of the salt, and that the alum of commerce is not pure sulphat of argil, but contains besides potash and ammonia. The proper sulphat of argil can, however, likewise be obtained by art. It is soluble, and crystallizes in thin flexible plates. This salt can combine also with an excess of acid, when it forms the acidulous sulphat of argil. The neutral sulphat of argil and potash is insipid, very sparingly soluble, and not crystallizable : the acidulous sulphat of argil, potash, and ammonia, forms common alum : the acidulous sulphat of argil and potash forms another salt, which has very similar properties. Of these salts, it is only necessary to notice the properties of alum.

Alum, in its usual state, is in large transparent masses ; it is likewise capable of crystallizing regularly. Its taste is sweetish and astringent ; it is soluble in 15 parts of cold and 2 parts of boiling water ; its solution reddens the vegetable colours. It undergoes the watery fusion ; and by a strong

strong heat is decomposed, its acid being partly expelled, and partly resolved into its constituent principles.

When alum is heated with carbonaceous matter, its acid is decomposed, and a portion of sulphur remains combined with the argil, or rather with the potash of the alum. A preparation of this kind affords the substance termed Pyrophorus, distinguished by its inflaming spontaneously when exposed to atmospheric air. It is prepared by exposing to heat in an iron pot 3 parts of alum with 1 part of flour or sugar, the mixture being constantly stirred till it is reduced to a grey powder. This powder is put into a phial slightly stoppt, which is exposed to a stronger heat, by being placed in a crucible, and surrounded with sand; it is kept in this heat till a blue flame which appears at the mouth of the phial ceases; the phial is then immediately removed, and stoppt.

This matter inflames in atmospheric air, especially when the air is moist; it also burns in oxygen gas, in nitrous gas, and in oxygenated muriatic acid. Its inflammability seems to be owing to its peculiar composition, the intimate mixture of its ingredients,

ingredients, and their dryness. It consists of argillaceous earth, with which is mixed a quantity of carbon in a state of extreme division, derived from the vegetable matter employed in its preparation, and a small portion of sulphuret of potash, which has also been formed during the process. When exposed to the air, the sulphuret of potash absorbs moisture, by which the temperature is raised: the sulphur has likewise a strong tendency to absorb oxygen; it is inflamed, and kindles the dry carbonaceous matter.

NITRAT of ARGIL can be obtained in small deliquescent crystals. It has an astringent taste. By the application of a moderate heat, it undergoes the watery fusion; and by a stronger heat, its acid is expelled, and decomposed.

Muriatic acid dissolves argillaceous earth; the solution, evaporated by heat, forms a gelatinous mass; by spontaneous evaporation, it forms rhomboidal crystals. It is decomposed by heat.

Carbonic acid scarcely combines directly with argil; but if to any of the argillaceous salts in solution, a solution of carbonat of potash be added, the

the carbonic acid is attracted by the argil, and a white powder is precipitated. It can scarcely be obtained dry, as the carbonic acid is expelled by a very moderate heat.

Argil has the property of combining, both in the dry and humid way, with the fixed alkalis; it likewise exerts an attraction in the humid way to lime and siliceous earths, forming with either of them compounds not soluble in water.

Argil, when pure, is infusible by any heat which a furnace can raise; but when mixed with the other earths, becomes much more easily fusible. Compounds of this kind form the different varieties of pottery and porcelain. The finest porcelain is composed of earths consisting nearly of flint and argil alone, with at least a small proportion of lime. In the coarser wares, the lime is more abundant, and oxyd of iron is always present in greater or less quantity, and communicates to the pottery a yellowish tinge. In the manufacture of the finer kinds of porcelain, the ingredients are carefully washed, dried, levigated, and made into a paste with water. This paste is thoroughly kneaded, so as to be uniform in composition;

tion; it is turned into vessels of any shape, which is baked in earthen pots to render them compact and hard: they are then covered with the materials for glazing. These consist of earths which, when mixed, form a compound more fusible than the porcelain itself; they are diffused in water, into which the baked vessels are put. These, after being dried, are again placed in earthen pots, and exposed to a very intense heat. The solid matter of the porcelain undergoes a semi-vitrification, whence it possesses all the hardness of glass, without its transparency; and has an additional value in being less brittle, and more able to bear sudden alterations of temperature. The matter adhering to the surface is more completely vitrified, and is therefore more smooth and impenetrable. The colours are fixed on by painting with enamels, which are fusible in a less heat than the glazing itself. The inferior kinds of porcelain and pottery are prepared in a similar manner from less pure materials; the glazing consists of siliceous earth with potash and oxyds of lead and tin, of the oxyd of lead alone, or of muriat of soda.

Argil is likewise capable of combining by fusion with the metallic oxyds.

Those fossils in which the argillaceous earth predominates are divided into two classes, —the Argillaceous Earths, and the Argillaceous Stones.

The Argillaceous Earths are distinguished by their diffusibility in water, and forming with it a paste more or less adhesive. They have an earthy texture, are hardened by heat, and scarcely effervesce with acids.

The purest of these, what is termed *Lac luna*, is a native carbonat of argil. It occurs in compact rounded masses, composed of very minute crystals; is white, without lustre or transparency; is light and friable. It effervesces with acids.

Clays form the principal family of the argillaceous earths. They consist of argil and fîlex in various proportions, with which are often intermixed magnesia, oxyd of iron, and other substances. Porcelain clay, or *kaolin*, is of a white colour, with shades of grey, yellow, or red; without
lustre

lustre or transparency; feels soft, and adheres slightly to the tongue; falls into powder when put into water. A clay of this kind, found in Cornwall, is composed of 66 parts of argil and 20 of fîlex. Potters clay, or pipe clay, is of a greyish white colour, has an earthy fracture, feels soft and unctuous, adheres to the tongue, is easily diffused in water, and when moistened is very ductile.

Smectis, or Fullers earth, has a greenish colour and earthy texture, feels unctuous, does not adhere to the tongue, and in water falls down into a powder, without forming an adhesive mass.—Lithomarge is distinguished from the other clays by the fineness of its texture, and by melting into a slag. Its colour is white or yellowish; its surface is smooth and soapy. Boles are of a red colour and earthy texture, without lustre; they contain a considerable portion of oxyd of iron, to which their colour is owing.—Ochres are clays impregnated with iron in various degrees of oxydation, which communicate to them various colours.—Tripoli and Terras, the two remaining argillaceous earths, feel harsh and dry; they imbibe
water

water, and when mixed with it become speedily indurated.

The second class of the argillaceous fossils are those which have the hardness of stones, and which do not fall into powder when immersed in water. Corundum, or Adamantine Spar, is distinguished from every other stone by its great hardness, which is such that it is used for polishing even the diamond. Klaproth supposed, that he had discovered in it the existence of a new earth; but by a second analysis, he found it to consist of from 84 to 89 of argil, 5 or 6 of flex, and from 1 to 7 of oxyd of iron.

Lillialite, or Lepidolite, is of a violet blue or purple colour, and, when in thin laminæ, of a silvery white; has a pearly lustre, with a slight transparency; hardness 4. or 5.; specific gravity 2.854. According to the analysis of it by Klaproth, it contains 54.5 of flex, 38.25 of argil, 4.000 of potash, 00.75 of iron and manganese, and 2.50 of water. Potash has likewise been discovered in it, in the proportion of 18 in the 100.

Cyanite is of a blueish grey colour with streaks of deep blue, of a pearly lustre, and transparency equal to 3, when it is in thin plates. According to Sauffure, it consists of 66 of argil, 13 magnesia, 12 filix, 1 lime, and 5 of iron.

Mica is generally found interspersed in other stones. It consists of thin plates, divisible, flexible, and slightly elastic, transparency in thin pieces 3.4.2. lustre nearly metallic. Its hardness is 6.; its colours are grey or yellowish, silvery white, green, or red. The fusibility of different varieties of it is very different. Colourless mica is stated by Mr. Kirwan to consist of 38 of filix, 28 argil, 20 magnesia, and 20 of perfect oxyd of iron.

Hornblende.—Common Hornblende is amorphous, of a grey or black colour, opaque, lustre 2, tough, with a hardness from 5 to 9, and specific gravity from 2.66 to 3.88— is fusible into a black glass. It consists of filix, argil, carbonat of magnesia, carbonat of lime, and oxyd of iron. The Basaltic Hornblende is crystallized, and is mostly found in Basaltes; its colour black or green, lustre 3, transparency

transparency in thin plates 1, texture foliated, hardness from 9. to 10., specific gravity 3.33 — is likewise melted by heat into a glass. Schistose Hornblende has a silky lustre and striated texture; is opaque, tough, and has a hardness from 7. to 9.

Under the name of *Trap* are comprehended several varieties of stones, which agree in their general characters. It is found in large masses, of a grey, blue, or purplish black colour, destitute of lustre and transparency, and presenting generally a texture composed of granular concretions. Its hardness is from 8. to 9. By heat it is melted into a black compact glass. Whinstone is a variety of this fossil. According to the analysis of it by Dr. Kennedy, it consists of silica from 46 to 48, argil from 16 to 19, oxyd of iron 16 or 17, lime 8 or 9, water 5 or 4, muriatic acid 1.

Basaltes is a similar fossil. Its texture exhibits a smaller and closer grain, and it is of a greater specific gravity than trap. But the principal difference between them is drawn from their figure, basaltes being always in large masses of a regular form,

form, generally columnar, straight or curved, perpendicular or inclined.

Argillite, Schistus, or Slate, is the last of the argillaceous stones. It is of a blue or greyish colour, with little lustre, and scarcely any transparency; its fracture approaches to the foliated; its hardness from 5. to 8. Its ingredients are argil, flex, lime, magnesia, and iron, united in various proportions in different specimens.

Sect. III. — — MAGNESIA.

THIS earth is not found pure in nature, but is obtained by art from some of its saline combinations, which exist in several springs, and in the water of the ocean. One part of sulphat of magnesia is dissolved in 20 of hot water, and a solution of pure potash or soda is added; the alkali, combining with the sulphuric acid, throws down the magnesia, which is washed and dried. Or the carbonat of soda or magnesia is used, a double decomposition thus takes place, and carbonat of magnesia is precipitated,

precipitated, from which, when dried, the carbonic acid may be expelled by heat. The pure earth, obtained by either process, is in the form of a very white spongy powder, soft to the touch, having a slightly bitter taste: specific gravity 2.330. It is infusible even by the most intense heat. It is nearly insoluble in water, and it does not form with that fluid an adhesive ductile paste. It slightly changes the vegetable colours to a green.

Magnesia combines with the acids; its attractions to them are weaker than those of the fixed alkalis, or of the alkaline earths: its salts are likewise partially decomposed by ammonia, one part of the magnesia being precipitated, and the other forming a triple compound with the acid of the salt and the ammonia.

SULPHAT of MAGNESIA is found native, both at the surface of the earth, and in mineral waters. Those of Epsom in England once afforded a large part of what is used in commerce of this salt, but it is now usually prepared from the liquor remaining after the extraction of muriat of soda from sea water; this liquor is a solution principally of muriat of magnesia: sulphat of iron is added, and the sulphat of magnesia

magnesia formed, as well as a portion of it originally contained in the sea water, is extracted by crystallization. A confused mass of needle-like crystals is obtained, which is deliquescent from a portion of muriat of magnesia adhering to it. This mass, when dissolved in water, affords pure sulphat of magnesia, by spontaneous evaporation in regular crystals. These effloresce on exposure to the air; are soluble in little more than their own weight of water at 60° , and in 3-4ths of their weight of boiling water. They consist of 29.35 parts of acid, 17 of earth, and 53.65 of water. The taste of this salt is extremely bitter,—and the bitterness of sea water, and many mineral springs, is partly owing to its presence. It is used in medicine as a cathartic. It is entirely decomposed by the fixed alkalis, partially by ammonia, and by double elective attraction by the fixed alkaline carbonats,

NITRAT of MAGNESIA is found in nitre beds, alongst with the nitrats of lime and potash. To obtain it pure, it is prepared by the direct combination of its principles. Its taste is bitter and acrid; by hasty evaporation of its solution, a mass of needle-like crystals is obtained; by spontaneous evaporation, it concretes in quadrangular prisms,

prisms. It is deliquescent ; is soluble in its weight of water at 60° , in half its weight of boiling water—is decomposed by heat. In its crystallized state, it consists of 22 of magnesia, 46 of acid, and 22 of water.

MURIAT of MAGNESIA. — This salt is found in sea water, in salt springs, and in mineral waters. It has a bitter nauseous taste, is very soluble in water, and can indeed be scarcely obtained in a solid state. It is likewise soluble in alcohol, and causes it to burn with a yellow or reddish flame. It is decomposed by heat, and suffers decompositions from the alkalis like the other magnesian salts. When dry, it consists of 31.07 earth, 34.59 acid, and 34.34 water.

PHOSPHAT, FLUAT, and BORAT of MAGNESIA, are salts scarcely known, and applied to no use.

CARBONAT of MAGNESIA is a more important compound, from its use in the practice of medicine. It is prepared by mixing together equal weights of sulphat of magnesia and sub-carbonat of potash, each of these salts being previously dissolved in twice its weight of water ; the sulphuric acid of the

the one salt is attracted by the potash of the other, and the carbonic acid of the latter is attracted by the magnesia of the former: the mixture is thrown into 8 parts of hot water, and is made to boil gently; the carbonat of magnesia is precipitated in a very light white powder,—it is washed with water, till it is tasteless, and is dried by a gentle heat. When properly prepared, it is perfectly white, insipid, having a very weak cohesion amongst its parts, and a specific gravity not more than 2.3. It is very sparingly soluble in water, requiring at least 2,000 times its weight, at the temperature of 60° . An excess of carbonic acid renders it more soluble; and by spontaneous evaporation of this solution, small crystals are obtained. Carbonat of magnesia is decomposed by heat, its carbonic acid being expelled. The proportions of its principles are various, according to the mode in which it is prepared; they vary from 45 to 55 of earth, from 25 to 30 of acid, and from 15 to 30 of water.

Magnesia combines with sulphur, forming a sulphuret soluble in water, which is decomposed both by acids and alkalis. It does not unite with phosphorus or carbon. Though infusible by itself,

self, it melts when mixed with some of the other earths, especially with the filiceous, argillaceous, and calcareous.

Under the magnesian genus of fossils are comprehended those in which magnesia predominates, and those in which, next to flint, it is the most abundant earth, and which at the same time are destitute of the hardness and infusibility of the filiceous genus, while they have the softness and unctuousity of the magnesian.

Chlorite is a fossil of a green colour, a scaly texture, without lustre, feels unctuous, and has a hardness, when indurated, equal to 6. It occurs amorphous and crystallized;—consists of magnesia, flint, argil, lime, and iron.

Talc is a fossil of a plated texture, the lamellæ being easily separated from each other: they are flexible but not elastic; their lustre is nearly metallic, with a considerable degree of transparency; their colour is greenish white, with sometimes a

tinge of red ; they feel unctuous. It does not effervesce with acids ; exposed to an intense heat, it loses its transparency, and becomes whiter ; urged with a stream of oxygen gas, it melts into an opaque green mass. It consists of 50 of flex, 44 magnesia, and 6 of argil.

Steatite, or Soap Rock, exists in various states of induration. It always feels soft and greasy ; is of a white, yellowish, or greenish grey colour ; often spotted or veined ; with little lustre or transparency ; its fracture is earthy or splintery ; its specific gravity from 2.4 to 2.7 ; is melted by a strong heat.

Serpentine is of a dark green colour, sometimes red or blueish grey, with spots or veins of other colours through its substance ; without lustre, and nearly without transparency, but susceptible of a fine polish ; fracture splintery ; its hardness from 6. to 7. ; specific gravity from 2.26 to 2.70 ; it feels soft, but with little unctuousity ; is infusible by the blow-pipe. It is found always amorphous. Its constituent principles are flex, magnesia, and iron, with the addition sometimes of argil. The proportions

proportions are 5 or 4 of filex to 3 of magnesia, and of oxyd of iron from 4 to 15 in the 100.

Asbestos is distinguished by its fibrous or striated texture, the fibres being either coarse or delicate, and frequently easily separated from each other; feels soft and greasy; hardness 6. or 7.; specific gravity from 2.54 to 2.57. Its colour is green, greenish grey, or yellowish grey. It does not effervesce with acids—is hardened and semi-vitrified by heat. It consists of filex, magnesia, iron, and argil, the filex being always in largest proportion,

Amianthus is a similar fossil, differing from asbestos principally in being more fusible by heat, its hardness being less, and its filaments being more separated and flexible.

Mountain Cork and Mountain Leather are the same fossil, the one being found in thin compact masses, the other in thin flat pieces. It is of a white, yellowish, grey, or brown colour; without lustre or transparency; its texture is fibrous; it is soft and somewhat elastic; and so light as to swim upon water, its specific gravity being from 0.68

to 0.69. It is fused by the blow-pipe, but with difficulty. It consists of filix, carbonat of magnesia, argil, carbonat of lime, and oxyd of iron.

Actynolite.— This stone is found in masses, composed of long and slender prismatic crystals, smooth or striated on the surface, or in aggregated masses of a foliated or striated texture. Its colour is most usually green, sometimes yellow or white; lustre varying from 1. to 4.; transparency 2.3 or 1. It is generally hard and brittle, and harsh to the touch; specific gravity, from 2.80 to 3.45. It changes colour when heated, and is melted into a glass by a strong heat. It consists of filix, carbonat of magnesia, carbonat of lime, argil, and oxyd of iron.

Jade, or Nephritic Stone, is found in round masses, or inhering in rocks; is of a dark green colour, verging often to blue; its lustre 1.; transparency 2.1; fracture splintery; hardness 10.; not brittle; specific gravity from 2.96 to 3.38; feels greasy. It loses its colour by heat, but cannot be fused. It consists of filix 47, carbonat of magnesia 38, argil 4, carbonat of lime 2, and iron 9.

Baikalite

Baikalite has been found only in Siberia ; it is in prismatic crystals, of an olive green colour, and smooth or striated surface ; lustre 1.2 ; transparency 1. ; fracture splintery ; hardness 8.9 ; specific gravity 2.200. It is composed of silic 44, magnesia 30, lime 20, oxyd of iron 6.

Boracite, the last of the magnesian fossils, is a compound of magnesia and lime with boracic acid, its proportions being 13 of magnesia, 11 of lime, and 68 of acid, with 1 of silic, 1 of argil, and 1 of iron. It occurs in small cubic crystals, of a greyish white colour ; lustre 3.2 ; transparency 2.3 ; hardness 9.10 ; specific gravity 2.566. It is melted by a strong heat ; it does not effervesce with or dissolve in acids, unless at a high temperature.

Sect.

Sett. IV. — — LIME.

THIS earth is found in great abundance in nature. It is the principal component part of marble, lime stone, plaster stone, marl, and many other fossils. It is contained in the water of the ocean, and in every kind of spring and river water : it is found in vegetables, and it is the basis of the bones, shells, and other hard parts of animals. To obtain it in a state of purity, the shells of marine animals, or some of the native combinations of it with carbonic acid, are exposed to a strong heat, by which this acid is expelled. The lime thus obtained generally contains minute portions of some of the other earths, but it can be obtained pure by dissolving it in an acid, and precipitating it by potash or soda.

Pure lime is perfectly white ; if in a coherent mass, it is moderately hard and brittle ; its specific gravity is 2.3. ; it has a pungent bitter taste, and

and acts as a caustic on animal matter. It is not fused by the most intense heat.

When water is poured on quicklime, or lime which has been deprived of its carbonic acid by heat, the water is absorbed with a hissing noise, the lime splits, and falls into a fine powder perfectly dry; and so much caloric is evolved, as to convert a considerable portion of water into vapour. The phenomena are owing to the strong attraction of the lime to water, and to the water entering into combination passing to the solid state. At the temperature of 60° , water dissolves about 1-600th of its weight of lime; at 212° , double that quantity: the solution has a styptic taste, and changes the vegetables colour to a green. By exposure to the air, it becomes turbid and insipid; the lime absorbing carbonic acid, and being precipitated in the form of carbonat.

Lime is capable of combining with all the acids. **SULPHAT of LIME** exists native in considerable quantity, and has been long known to chemists under the names of Selenite, or Gypsum. It forms immense strata; it is to be found in every soil, and it is contained in the waters of the ocean, and

and in almost all river and spring water, communicating to the latter the quality termed their Hardness.

Native sulphat of lime occurs in a powdery form, white, without transparency or lustre, or in a state of greater hardness, either amorphous or crystallized. In this state its texture is laminated, foliated, or fibrous, forming so many varieties; their colours are white, with various shades of gray, yellow, green, or red; their lustre from 4. to 3. or 1., their transparency 2. 3. 1., their hardness 4. and specific gravity from 1.870 to 2.320. They sometimes effervesce with acids from the presence of carbonat of lime, and are entirely soluble in sulphuric acid with the assistance of heat.

Sulphat of lime is soluble in 500 times its weight of water at 60°, and in 470 of boiling water. Exposed to heat, it appears to boil or effervesce, owing to the expulsion of its water; it becomes opaque, and falls into a white powder. This when mixed again with water absorbs it rapidly, and though even of the consistence of cream, becomes soon solid, by a species of hasty crystallization. This forms plaster or stucco work. When exposed

exposed to a more intense heat, it vitrifies, from the mixture of some argillaceous or siliceous earth. When pure, it is absolutely infusible. Heated by the flame of the blow-pipe, its acid is partially decomposed, its oxygen being abstracted by the combustible matter in the flame.

Sulphat of lime is decomposed by barytes and the two fixed alkalis, by boiling it with them in water; and more easily by double affinity by the alkaline carbonats. It is also decomposed by heating it with charcoal, the carbon abstracting its oxygen. It consists of 32 parts of lime, 46 of acid, and 22 of water.

NITRAT of LIME. — This salt is generally found alongst with nitrat of potash, and it has been discovered in some mineral waters. When the solution obtained by the direct combination of its principles is evaporated to the consistence of thin syrup, it affords slender prismatic crystals. These are very deliquescent, are soluble in 8 parts of water at 60°, and in an equal weight of boiling water. Exposed to heat, they are melted and decomposed. When thrown on burning fuel, it

detonates slightly. It contains 32 parts of lime, 574.4 of acid, and 16.56 of water.

MURIAT of LIME.—This salt is found in salt springs, in the water of the ocean, and in many mineral waters. Its taste is bitter; it is soluble in $1\frac{1}{2}$ part of water at 60° , and in less than an equal weight at 212 . Its saturated solution affords, on cooling, prismatic crystals. These are deliquescent; exposed to heat they are melted, and part of the acid is expelled. The remaining mass is highly phosphorescent. This salt in its crystallized state consists of 44 of lime, 31 of acid, and 25 of water. It is decomposed by several of the acids, by the fixed alkalis and barytes, and by double affinity by the alkaline carbonats. When a saturated solution of it is mixed with a saturated solution of carbonat of potash, a double decomposition is instantly produced, muriat of potash and carbonat of lime are formed, and the water present not being sufficient for the solution of the two salts, and being even absorbed by them, a solid mass is formed.

BORAT of LIME is very sparingly soluble in water, and is fused by heat. It is decomposed
by

by a number of the acids, which combine with the lime, and by barytes, which attracts its acid.

FLUAT of LIME.—Lime saturated with fluoric acid forms a solution, which, by evaporation, forms a gelatinous mass; it is insipid, and sparingly soluble in water. There is no substance that has a stronger attraction to its acid than its base has; but it is decomposed by the alkaline carbonats by double affinity, and by the sulphuric acid, which displace the fluoric,

This compound exists abundantly in nature, and has been long known to mineralogists by the name of Fluor Spar. Scheele discovered its composition. It is found amorphous and crystallized; its texture is foliated—in one variety compact, and in another earthy; its hardness from 7. to 8.; its specific gravity from 3.09 to 3.19; its lustre 2.3., transparency 2.3.4.; is susceptible of a fine polish. Its colours are very various, and in general beautiful; the purple is the most common, then the yellow, green, or blue — sometimes it is colourless, and perfectly transparent. It is insoluble in water, and is not acted on by the air; decrepitates on exposure to heat, and shines with a blue light when

when thrown in powder on a hot iron, its colour is at the same time destroyed. It requires a very intense heat to melt it alone, but when mixed with other earths, or exposed to heat in a clay crucible, it melts more easily. It does not effervesce but with the sulphuric acid, and with it very slightly. According to the analysis of it by Scheele, it is composed of 57 of lime, 16 of acid, and 27 of water; to which, in different specimens, are added variable proportions of phosphoric acid, silica, argil, iron, and cobalt.

PHOSPHAT of LIME.—This saline combination is found native. It is the fossil termed Apatite, which occurs crystallized and amorphous; its colour grey, green, red, or purple; its lustre 2.3; transparency, 2.3.4; its hardness from 6. to 7.; its texture lamellated. When heated, it is phosphorescent. According to Klaproth's analysis, it consists of 55 of lime and 45 of phosphoric acid.

Phosphat of lime is likewise found in the ashes of vegetables, and it is the solid basis of the bones and other hard parts of animals.

This

This compound is nearly, if not entirely insoluble in water; it is vitrified, but not decomposed by heat. The alkalis do not decompose it, as the lime has an attraction stronger than their attraction to phosphoric acid. The acids, particularly the nitric, sulphuric, and muriatic, were supposed to be capable of decomposing it completely, by combining with the lime, and disengaging the acid; but Fourcroy and Vauquelin have shewn, that the decomposition is only partial, and is the effect of concurrent affinities, of the phosphoric acid to lime, and of phosphat of lime to an excess of acid. The products, therefore, are sulphat of lime and acidulous phosphat of lime: the latter is soluble in water, and forms a solution having all the acid properties. According to the experiments of these chemists, the neutral phosphat of lime contains 41 parts of acid in the 100, the acidulous 65.

CARBONAT of LIME. — This compound is nearly insoluble in water, unless when combined with an excess of acid, which renders it more soluble. It cannot be crystallized by art, though it exists in a crystallized state abundantly in nature. It is decomposed by heat, its carbonic acid being expelled.

expelled. This decomposition of native carbonat of lime is carried on, on a large scale, to procure lime for the numerous purposes to which it is applied. Pieces of lime stone are exposed in a kind of open furnace to a degree of heat sufficient to drive off the carbonic acid, care being taken not to apply too strong a heat; as the lime, though infusible when pure; would be semi-vitrified, from its union with siliceous or argillaceous earth always present, in greater or less quantity, in the lime stone; and from this semi-vitrification, the lime would be incapable of slaking.

This salt, like the other carbonats, is decomposed even by the weaker acids combining with its base, and disengaging its acid with effervescence. This property of effervescing on the contact of a weak or diluted acid, is a convenient test for distinguishing those fossils in which the carbonat of lime predominates. The alkalis are incapable of decomposing it. It is decomposed by double affinity by various neutral salts.

The compound of carbonic acid and lime exists in great abundance in nature, forming the various fossils termed Calcareous Spar, Marble, Lime Stone,

Stone, Chalk, and Marl, which, though they run into each other, are still distinguished by varieties in figure, texture, and other external characters.

The first family, the Calcareous Spars, is crystallized, amorphous, and stalactitical. The crystals are generally rhomboidal, but often likewise prismatic, or of various other forms. They are distinguished by their laminated texture, and by their fragments being rhomboidal, and possessing the property of double refraction; they have often the transparency of the siliceous crystals, but want their hardness, this being not more than 5. or 6., so that they can be scratched by the knife; their lustre is 3.2.; their colour very various. They lose their lustre on long exposure to the air; become opaque by heat, and by a strong heat are decomposed, the carbonic acid being expelled. They consist of about 55 of lime, 34 of acid, and 11 of water. Calcareous spar, in its amorphous state, has less transparency and lustre, and its fracture presents distinct granular concretions. The Stalactites are distinguished by their fibrous or striated texture, and their particular shapes; they are only semi-transparent, with a lustre not exceeding

1., a hardness from 5. to 7. They are formed at the tops of caverns or crevices, by deposition from water filtering loaded with carbonat of lime. The Stalagmites are similar depositions, formed by the water dropping on the floor of the cavern.

Marble is distinguished from the preceding varieties, by being amorphous, existing in large strata, and by greater density, hardness, and specific gravity. From the closeness of its texture, it is capable of taking a fine polish. Marbles appear under a variety of forms, distinguished by colours, impressions, and fineness of grain. White marble is nearly pure carbonat of lime; many of the coloured marbles likewise contain from 90 to 96 parts of it in the 100, though there are others which do not contain more than 60 or 65. The other ingredients are filix, argil, oxyd of iron, and sometimes magnesia or barytes.

Lime stone passes into marble by insensible gradations, the differences between them being only in the degrees of the same qualities. Lime stones are of a coarser texture, more friable, and without lustre or beauty of colour. They are also more impure, containing more siliceous and argillaceous earths and oxyd of iron.

Chalk

Chalk is distinguished from lime stone by its whiteness, and by having little or no coherence; it is so soft as to stain the finger; is destitute of lustre and transparency; adheres slightly to the tongue, and falls into powder in water. Its specific gravity is from 2.315 to 2.657. It consists of 53 of lime, 42 of carbonic acid, 2 of argil, and 3 of water.

Marl is the last important variety of native carbonat of lime. It exists in an earthy or semi-indurated form, of a yellowish or grey colour, without lustre or transparency; has a specific gravity from 1.6 to 2.4; crumbles on exposure to the air, and in water falls into a powder, without forming with it a ductile paste. It contains from 66 to 80 in the 100 of carbonat of lime, the remainder being argillaceous and siliceous earths, with oxyd of iron.

Besides these varieties of carbonat of lime, there are some fossils which contain it, combined with much larger quantities of foreign substances. Such are the Sidero-calcite, or Pearl Spar, found in a crystallized state, and containing, in the 100,

35 of oxyd of manganese and 5 of iron—the Baryto-calcite, likewise in the state of crystals, containing 8 parts of carbonat of barytes, with 92 of carbonat of lime—the Muri-calcite, or Compound Spar, consisting of 52 of carbonat of lime, 45 of carbonat of magnesia, and 3 of iron and manganese—Argentine, a substance of a lamellated texture, lustre 3.2, transparency i.o.i.5, hardness 5. or 6., specific gravity 2.647, which effervesces strongly with acids, and is supposed to consist of magnesia, argil, and oxyd of iron—the Elastic Marble, or Dolomite, which is lime supersaturated with carbonic acid, and mixed with argil, magnesia and iron—and lastly, the Swine Stone, which is carbonat of lime impregnated with bitumen, and distinguished by the disagreeable smell it gives out on slight friction.

It has been a subject of dispute among geologists, whether the immense strata of carbonat of lime in its numerous varieties are primitive, or have originated from the decay of marine animals, or other organic beings. It is probable that much of it may have been derived from the latter source, since remains of organised matter are often found in its substance. But that it is not exclusively so seems

seems now agreed, since immense strata have been observed without any vestiges of such substances, and in close connection with strata allowed to be primitive, and since even these primitive strata contain it as a constituent part.

There remain to be considered some combinations which pure lime forms with other chemical agents.

With sulphur it combines with facility, either by fusion, or by boiling them in water. In the latter case, sulphurated hydrogen is also formed. The sulphuret of lime is similar in its properties to the alkaline sulphurets, and is decomposed, like them, by the acids. It has lately been proposed as a substitute for the fixed alkalis in bleaching; the alternate immersion of the cloth in the oxygenated muriatic acid and in a diluted solution of sulphuret of lime, produce, it is affirmed by Mr. Higgins, the same effect as the alternate application of the acid and of a solution of potash or soda.

Lime

Lime likewise combines with phosphorus. If these two substances, in the proportion of 2 parts of the former to 1 of the latter, be put into a coated glass tube in alternate strata, and exposed for a short time to a red heat, they combine, and a phosphuret of lime, of a brown or black colour, is formed. When this is thrown into water, it immediately decomposes it, one part of the phosphorus attracting its oxygen, another part combining with its hydrogen, and forming phosphorated hydrogen, which is disengaged in the gaseous form, and inflames as it escapes from the surface of the water.

Lime combines with the other earths, at least with flint and argil, by fusion, forming a kind of porcelain or enamel. It likewise exerts an attraction to the earths in the humid way, combining with flint, with barytes, or argil, when each earth has been dissolved in the same solvent, and their solutions are mixed together. On this in part is founded the preparation of Mortar.

Sect.

 Sect. V. — — BARYTES.

THE existence of this earth in a state of combination with sulphuric acid, in a fossil known to mineralogists by the name of Heavy Spar, was discovered by Scheele. It has been named Barytes, from its native compounds having a greater specific gravity than other fossils not metallic.

Barytes forms a component part of comparatively few fossils; it is found principally combined with sulphuric and carbonic acids.

Native Sulphat of Barytes is often met with, and is indeed a common matrix of metals and their ores. It is distinguished by its great specific gravity, which is from 4.400 to 4.865. Its hardness is from 4. to 5. or 6.; it occurs amorphous and crystallized; its texture is earthy, compact, foliated or striated,—that of the crystallized is generally foliated; the crystals have a transparency 4.3.; lustre commonly 3. The colours of both are

are various, generally white, or with a shade of yellow or red. The composition of the different varieties is somewhat different. The purest crystallized kinds contain 67.2 of barytes, and 32.8 of sulphuric acid. Others contain sulphat of lime, flex, and oxyd of iron in various proportions. This compound is insoluble in water; it dissolves in the concentrated sulphuric acid with the assistance of heat, and is precipitated by the addition of water. Exposed to heat it decrepitates, and by an intense heat is fused.

The Lapis Hepaticus, or Liverstone, is a distinct species. It contains 38 of sulphat of barytes, 33 of flex, 22 of argil, 7 of gypsum, and 5 of petroleum. It emits when rubbed a foetid smell: its specific gravity is 2.666.

Carbonat of barytes has been found only in Lancashire in England, and in Siberia. It occurs in solid rounded masses, and likewise, though rarely, crystallized; its texture is fibrous or striated, sometimes compact; its colour greyish white or milk white; its transparency 2.3., lustre 2., hardness from 5. to 6., specific gravity from 4.300 to 4.338. It is soluble in the nitric and muriatic acids

acids with effervescence; it loses the degree of transparency it possesses when exposed to heat; but is not fused and scarcely decomposed. It requires for its solution 4,300 times its weight of cold water, 2,300 times of boiling water. According to the experiments of Dr. Withering, it consists of 208 of carbonic acid, and 78.6 of barytes.

The pure earth is usually obtained from the native fulphat. One part of it is mixed with one-fifth part of charcoal powder, and exposed to a red heat for an hour; a fulphuret of barytes is thus obtained, which may be decomposed by muriatic or nitric acid: or 1 part of the powdered fulphat is exposed to a moderate heat, with $1\frac{1}{2}$ parts of dried carbonat of soda or potash, by which a double decomposition is effected; the alkaline fulphat, and any superfluous alkali, are carried off by washing, and diluted muriatic acid is added to the remaining carbonat of barytes. The muriat of barytes which is thus obtained, was usually decomposed by adding a solution of carbonat of potash to it, and from the carbonat of barytes thus formed, expelling the carbonic acid by heat—this required, however, an intense heat, by which the barytic earth was partly vitrified,

vitriified, from combining with the earth of the crucible. A preferable process, therefore, is to use the nitric acid, and decompose the nitrat of barytes by heat, for which a very moderate increase of temperature is sufficient.

Barytes, obtained by this latter method, is in the form of a grey, somewhat porous mass, extremely pungent and caustic: it flakes like lime, but with still greater rapidity on exposure to the air, or by pouring water on it, — the water being absorbed, the mass falling into a white powder, and caloric being rendered sensible. This powder is soluble in 25 parts of water at 60°, and in 2 parts of boiling water; the latter solution crystallizes on cooling. It is entirely infusible by heat alone, but melts when mixed with other earths. Its specific gravity is 4.000.

Barytes is distinguished amongst the earths by the strength of its attraction to the acids, which is superior to that of any other substance. Hence it is capable of decomposing all the neutral salts. Another property by which it is distinguished is, being precipitated from its solutions in acids by
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the prussiat of potash,—a property possessed only by the metallic oxyds.

SULPHAT of BARYTES, formed by the direct combination of its principles, is similar in its properties to the native sulphat. It consists, according to Klaproth, of 67 of earth and 33 of acid. It is capable of uniting with an excess of acid, forming a combination which is again decomposed by water.

NITRAT of BARYTES, formed by the combination of its principles, is soluble in 12 parts of water at 60°, and in a less quantity of boiling water; the latter solution crystallizes on cooling. Exposed to heat it is decomposed; its acid being resolved into oxygen and azotic gases, and its earth remaining pure. It has a pungent caustic taste—consists of 57 of earth, 32 of acid, and 11 of water.

MURIAT of BARYTES is usually prepared by adding muriatic acid to the product of the decomposition of the sulphat by charcoal, or carbonat of potash, or soda. The solution is filtered, and, by evaporation, crystallized. Its crystals are soluble

in 6 parts of water at 60° , and in a less quantity of boiling water. The taste of its solution is harsh and styptic. It is decomposed by the sulphuric, nitric, oxalic, and tartareous acids. From the great insolubility of the sulphat of barytes, the muriat is employed as a test to discover the presence of sulphuric acid in any compound. It consists of 64 of earth, 20 of acid, and 16 of water.

The other acids, the phosphoric, fluoric, boracic, and carbonic, combine with this earth, and form salts which are not important. There is a difference between the native carbonat and that prepared by art, in their facility of decomposition by heat, the former retaining its acid much more strongly than the latter. In its other properties, the artificial carbonat is similar to the natural.

Barytes combines with sulphur. The compound is soluble in water, and by evaporation can even be made to crystallize. It is decomposed by the acids. It also combines with sulphurated hydrogen, and forms a compound capable of crystallizing.

Barytes

Barytes is also capable of combining with phosphorus. The compound decomposes water rapidly, and disengages phosphorated hydrogen.

It combines, both in the humid way and by fusion, with several of the earths, particularly with flint and argil.

Barytes is poisonous to animals. In a small dose the muriat is employed in medicine.

Sect. VI. — — *STRONTITES.*

STRONTITES was first observed in a native combination with carbonic acid, in the mine of Strontian in Argyleshire, whence its name has been derived; and its characters as a peculiar earth, were first discovered by Dr. Hope. The same combination has likewise been found in Transylvania, and the sulphat has been discovered in France, Saxony, Hungary, and England. Its existence has not been detected in any other fossil.

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The native carbonat of strontites is found both in solid masses, and in prismatic or columnar crystals. Its colour is dull white, or light green; its texture striated, the fibres disposed in a radiated manner; its transparency 2., lustre from 2. to 3., hardness 5., specific gravity from 3.4. to 3.726. It differs from carbonat of barytes, with which it had been confounded, in its colour and its inferior specific gravity, and in allowing its carbonic acid to be expelled by heat more completely, and with less difficulty. According to Dr. Hope's analysis, it consists of 61.21 of earth, 30.2 of acid, and 8.59 of water; according to Klaproth's, of 69.15 of earth, and 39 of carbonic acid, with a little water.

The sulphat of strontites which has been found near Bristol in England, is in general in the form of a confused mass of bevelled plates, adhering firmly together, semi-transparent, and having a light blue tinge. Another variety is found of a granular texture, having much less coherence than the other. Their specific gravity is from 3.880 to 3.960. From Mr. Clayfield's analysis of this fossil, it appears to consist of, 58.25 parts strontites, and 41.75 parts sulphuric acid, with a small proportion of iron. A variety discovered in Pennsylvania

vania was found by Klaproth to be of almost precisely the same composition. Another found in France, according to the analysis of it by Vauquelin, consists of 54 strontites and 45 sulphuric acid, with 1 of carbonat of lime.

From these native combinations, the pure earth may be obtained by processes similar to those by which pure barytes is obtained.

Strontites resembles barytes in its most essential properties, in its great specific gravity, in its strong attraction to the acids, in its solubility in water and capability of crystallization, in forming with muriatic acid soluble and crystallizable salts, with the sulphuric and carbonic acids insoluble salts, and in existing in nature combined only with these two latter acids. Still there are differences between them sufficient to shew that they are distinct earths, and to distinguish them from each other. The specific gravity of strontites is inferior to that of barytes; and the same difference obtains in their native combinations: the attraction of the former to the acids is inferior to that of the latter: the salts which they form are different in their properties, particularly with respect to solubility,

lubility, those of strontites being more soluble than those of barytes: strontites is not precipitated from its solution in acids by the gallic acid or by prussiat of potash, which barytes is: the salts of strontites, the muriat for example, dissolved in alkohol, cause it to burn with a purplish red flame; those of barytes produce only a yellow flame: and lastly, barytes is poisonous to animals, while strontites is not more active than the other earths.

Strontites has a sharp caustic taste. It is flaked by exposure to the air, or when moistened with water—is soluble in 100 parts of water at 60° , and in much less boiling water, the latter solution crystallizing on cooling. It is infusible. Its solution changes the vegetable colours to a green.

It combines with the acids, and exerts an attraction to them inferior only to those of barytes. The *SULPHAT of STRONTITES* is very sparingly soluble in water, though more so than that of barytes; like this latter, it is dissolved by sulphuric acid, and precipitated by water. The *NITRAT of STRONTITES* is soluble in an equal part of water at 60° , and in nearly half its weight at 212° . The crystals which the latter solution affords are octohædral.

octohædral. They consist of 36 of earth, 13 of acid, and 33 of water. The MURIAT of STRONTITES is soluble. One part of cold water can dissolve $1\frac{1}{2}$ parts of it; boiling water, more than four parts of it. Its solution easily affords needle-like crystals, which are not deliquescent. They contain 40 of earth, 18 of acid, and 42 of water. The CARBONAT of STRONTITES may be formed by the direct union of its principles, or by adding to the solution of the muriat or nitrat, a solution of carbonat of potash or soda, when a double decomposition ensues. The carbonat is insoluble and insipid; like that of barytes, it is more easily decomposed by heat than the native carbonat.

Strontites combines with sulphur, sulphurated hydrogen, and phosphorus, forming compounds similar to those of barytes. It unites with argil and flint in the humid way, and also by fusion.

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SECT. VII. — — ZIRCON.

THIS earth has been discovered by Klaproth in the zircon, or jargon, a gem brought from the island of Ceylon. It consists of 31.5 of silica, 0.5 of iron and nickel, and 68. of this new earth, which has been named Zircon. When obtained pure, zircon is in the form of a white powder, having a specific gravity equal to 4.300, rough to the touch, and insipid. It is insoluble in water, but forms with it a gelatinous mass, which when dried becomes hard and semi-transparent. It is infusible by the blow-pipe, but by a more intense heat is vitrified, and becomes extremely hard. It does not melt with the alkalis, but with borax it forms a transparent colourless glass. It combines with the acids, and its salts are decomposed, not only by the fixed alkalis, but by ammonia: they are likewise decomposed by heat. It is insoluble even by boiling in a solution of potash or soda. By these properties this earth may be distinguished from every other.

SECT.

 Sect. VIII. — — — GLUCINE.

This earth was discovered by Vauquelin in the beryl and the emerald, combined with silica, argill, lime, and oxyd of iron in the one, and the same earths with oxyd of chrome in the other. It is white, light, soft to the touch, adheres slightly to the tongue, is insipid. It is insoluble in water, and infusible by itself in the fire. It is soluble in almost all the acids, and exerts attractions to them intermediate between those of magnesia and argill. Its salts are in general soluble, and have a highly saccharine taste,---a property by which it is distinguished from every other earth. It is likewise soluble in the pure fixed alkalis, and in carbonat of ammonia, but not in ammonia itself.

Sect IX.— — — YTTRIA.

THE discovery of this earth by Gædolin, in a fossil termed Ytterby from the place where it is found, has been confirmed by Vauquelin. The following are its characters: It is white, smooth, and insipid; is infusible alone, but vitrifies with borax. It combines with the acids, and is precipitated from these solutions by ammonia and by prussiate of potash. It is not soluble in the fixed alkalis, by which it is distinguished from glucine, which it resembles in several of its properties. Its attractions to the acids are also in general stronger than those of this earth, and its saline compounds have not the same taste. As it is precipitated by prussiate of potash, and even by tanin, and as some of its salts are coloured, it has been considered as the link which connects the metals and earths.

Sect. X. — — AUGUSTINE.

AUGUSTINE is a new earth, said to have been discovered in the Saxon beryl by Trommsdorff. It is white and insipid; when moistened with water, it is somewhat ductile, but is not soluble in that fluid. Exposed to a strong heat, it becomes extremely hard. It combines with the acids, forming salts which are void of taste; and from this property its name has been derived. It does not combine either in the humid or dry way with the pure alkalis or with their carbonats.

CHAP. VII.

MINERAL WATERS.

MINERAL WATERS may, with propriety, be considered after the metallic and earthy fossils, as it is from these that they derive in general their peculiar properties. Though all waters, that which descends in rain excepted, may be stiled Mineral, as they contain more or less of saline and earthy matters, yet the term is restricted to those in which the quantity of matter dissolved is such, as gives the water peculiar taste or smell, renders it capable of producing peculiar effects on the animal system, or communicates to it peculiar chemical properties.

The substances found in mineral waters are extremely numerous. The most common are, carbonic acid; sulphurated hydrogen; sulphureous acid;

acid ; carbonats, sulphats, and muriats of soda, lime, and magnesia ; and carbonat and sulphat of iron. These are variously intermixed, and the water is classed as acidulous, sulphureous, saline, or chalybeate, according to the ingredients which predominate in it.

The first step in the analysis of a mineral water is to ascertain the substances it contains.

Carbonic acid, when uncombined, or in excess, may be discovered by the pungent acidulous taste of the water, and its sparkling appearance when poured into a glass. The chemical tests to discover it are infusion of litmus, any of the strong mineral acids and lime water, the first receiving from the mineral water containing it an evanescent redness, the acids exciting effervescence in it, and lime producing a precipitate soluble with effervescence in any of the acids. The quantity may be ascertained by exposing the water to heat in a retort, collecting the gas in a jar over mercury, and introducing to it a solution of potash, by which the carbonic acid gas is absorbed.

Sulphureous

Sulphureous acid is discovered by its smell, by giving a permanent red colour to a solution of litmus, and by rendering colourless an infusion of roses. Its quantity is estimated by expelling it, exposing the gas to a solution of potash, and obtaining the fulphite of potash; or by adding to it sulphurated hydrogen as long as any diminution of volume is produced. By this means it may be separated from carbonic acid.

Sulphurated hydrogen, existing in a water, is discovered by its smell, by the deposition of sulphur from it on exposure to the air or on the addition of nitric acid, by blackening silver or mercury immersed in it, and affording a dark-coloured precipitate with acetite of lead. The quantity of it has been estimated by expelling it from the water by the application of heat, but the whole of it cannot thus be expelled. Mr. Kirwan's method is to inclose a quantity of the water in a jar, with atmospheric air, which is inverted in water: nitrous gas is passed through the water, so as to combine with the oxygen of the atmospheric air: nitrous acid is formed, and this, being absorbed by the water, decomposes the sulphurated hydrogen; the quantity that has been present

lent may be discovered from the quantity of sulphur precipitated.

When sulphurated hydrogen and carbonic acid exist together in a mineral water, the air obtained from the water by heat is exposed to nitrous acid, by which the sulphurated hydrogen is immediately absorbed and decomposed.

After the gaseous substances existing in mineral waters have been ascertained, the solid contents are to be examined.

The mineral acids, when uncombined with any base, are discovered by the water giving a permanent red colour to vegetable infusions—the alkalis, by changing them to a green. Those substances, however, are very seldom found.

The neutral and earthy salts are the chief ingredients of mineral waters. We have to ascertain the acids they contain, and the bases with which these are united.

Sulphuric acid, in combination with the alkalis or earths, is detected by muriatic of barytes, acetite

tite of lead, and nitrat of mercury. The first is the most delicate test. To prevent it, however, from affording a precipitate, from the presence of the alkaline or earthy carbonats, it is necessary to add, previously to the water, a small quantity of pure nitric or muriatic acid.

Muriatic acid is detected by the nitrat of silver. The same caution must be used in employing this test as with respect to the muriat of barytes in detecting sulphuric acid. It is also precipitated by the alkaline or earthy sulphats; and these must therefore be also previously decomposed by nitrat or acetite of barytes.

Carbonic acid, in a state of combination with the alkalis, may be discovered by the effervescence produced by the addition of sulphuric acid, and by muriat of barytes forming a precipitate soluble with effervescence in nitric or muriatic acid. The alkaline carbonats are distinguished by their power of changing the vegetable colours; the earthy and metallic carbonats, by being precipitated when the water is partly evaporated.

These

These are the acids usually met with in mineral waters. They are commonly combined with the fixed alkalis, lime, magnesia, or argil, or with oxyd of iron.

Lime is *immediately* precipitated from all its combinations by oxalic acid. Some of the mineral acids, however, either decompose this acid, or hold dissolved the precipitate it forms with the lime. This fallacy is in a great measure guarded against by using, not the pure acid, but oxalat of potash. Sulphuric acid is also a test to discover lime; but it is one of much less delicacy.

Ammonia and lime water are the tests of magnesia, the former precipitating it partially, the latter entirely. In order that it may be accurate, it is necessary to remove any carbonic acid which may exist in the water, by adding nitric acid; and any sulphuric acid, by barytes. Another source of fallacy, not less important, arises from argil being precipitated by these tests, as well as magnesia. The nature of the precipitate may be discovered by dissolving it in nitric or muriatic acid; and again precipitating the solution by carbonat

of potash. If this dried precipitate be subjected to the action of diluted sulphuric or muriatic acid, it will be immediately dissolved if the earth be magnesia, while, if it be argil, it will be scarcely touched. Another test which discriminates between these earths is carbonat of ammonia, which affords a precipitate with the argillaceous, but not with the magnesian salts. — By these tests, argil is likewise discovered.

Of the metals, iron is the principal one found in mineral waters. It is discovered by the gallic acid, or rather the infusion of galls, which produces a purple or black colour with it, or by the prussiat of potash, which gives it a blue colour. The former is more accurate, and is even more delicate than the latter: the colour it produces is varied, however, in its shade, by certain salts which the water may contain. By applying this test before and after evaporation or ebullition of the water, we discover whether the iron is combined with carbonic or sulphuric acid. If it be with carbonic, the colour is not produced after the water has been boiled, as the oxyd is precipitated.

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The alkalis, when in a state of combination, cannot be discovered by any very striking tests. When combined only with carbonic acid, they retain the power of changing the vegetable colours; and the peculiar salts which they form with the different acids serve to distinguish them. With oxalic acid, soda forms a salt sparingly soluble; while potash forms, with the same acid, a salt easily dissolved. With tartarous acid, on the contrary, soda forms a soluble salt; while with potash, an acidulous tartarite is formed, of comparatively sparing solubility.

Siliceous earth is contained in some waters, not combined, however, with any acid. A portion of potash likewise generally exists in such waters; but this is either in the state of carbonat, or in such small quantity that it cannot be considered as the solvent of the flint. This earth may be discovered by evaporating the water, and adding to the solid matter nitric or muriatic acid; the flint will remain undissolved; and its nature may be still more clearly proved by fusing it with either of the fixed alkalis.

Besides

Besides these tests, by which the constituent parts of the usual saline combinations in waters may be discovered, there are others, by which several of these combinations may be directly detected. Of these alcohol is the principal. It precipitates sulphat of lime, the alkaline sulphats, and the sulphat of argil and magnesia, while it dissolves the muriats or nitrats of lime and magnesia. From these differences in solvent power, alcohol is employed with advantage in the analysis of mineral waters, to discover and separate these salts.

Evaporation is another mean by which the existence of several saline combinations in mineral waters may be discovered, being separated at certain stages of the evaporation. Siliceous earth, sulphat of lime, and the earthy carbonats, may thus be obtained.

Lastly ; by exposure to the air, several substances are discovered. Thus oxyd of iron is precipitated, as is also sulphur, from sulphurated hydrogen.

The

The second part of the analysis of mineral waters is the estimation of the quantities of the substances which they contain. This, however, is a subject of which an abridged account would be useless, as it consists entirely of minute details. It is fully treated of by Mr. Kirwan in his treatise on Mineral Waters.

PART

PART III.

OF

VEGETABLE AND ANIMAL SUBSTANCES.

THE substances formed in the animal and vegetable systems are all compounds, and are distinguished from those which have hitherto been noticed, by certain chemical characters. Though numerous, and extremely diversified in their properties, they consist of nearly the same principles, united only in peculiar proportions and modes of combination. These principles are combined in the vessels of the organic being, under circumstances indefinitely varied, and which art cannot imitate ; and therefore similar compounds cannot be formed by the usual chemical means. They exist in these

these compounds with their mutual attractions so nicely balanced, that the slightest causes are sufficient to alter that balance : these compounds are, therefore, easily decomposed ; they are entirely changed by exposure to a moderate heat ; they are easily acted on by the different chemical agents ; and they are subject to spontaneous decomposition, arising from the re-action of their principles on each other, and constituting the processes of fermentation and putrefaction. As the simple principles of which they are formed have strong reciprocal attractions, their analyses are always of the complicated kind : when decomposed, their principles do not pass off pure, but enter into new combinations with each other. And, lastly, as their principles are nearly the same in all, the same, or very similar products are afforded by the analysis of each. By these characters, the products of organisation are peculiarly distinguished.

The ultimate elements of these substances are chiefly carbon, oxygen, and hydrogen, in the vegetable products ; and the same principles, with azot and phosphorus, in the animal substances. Sulphur, iron, manganese, gold, filix, lime, and
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the alkalis, are likewise discovered in their composition, but only in inconsiderable proportion. Lime and iron are the most constant, and those which are present in the largest quantity.

The vegetable differ from the animal substances in certain chemical characters. The latter are more peculiarly subject to the process of putrefaction; and when decomposed by heat, besides the empyreumatic oil and acid, the hydrocarbon, and carbonic acid, which vegetable matter affords, they yield a large quantity of ammonia, and generally peculiar combinations of hydrogen with sulphur, phosphorus, and azot. It is upon the presence of these three substances in their composition that these peculiarities principally depend.

OF VEGETABLE SUBSTANCES.

CHAP. I.

OF THE FORMATION OF THE VEGETABLE PRODUCTS.

THE Structure of vegetables is in many respects similar to that of animals. It consists of solid parts through which vessels of different kinds are distributed, and organs, in which functions, similar to those of animals, are performed.

The solid parts are the stem, or trunk, the branches, and the root. These consist of the pith or internal soft substance; the wood, which is of a denser texture; and the covering, or bark, subdivided into the epidermis, or outer coat, the cellular tissue, or envelope, including a green pulpy matter, and the cortical layers, or strata, next to

the wood. The root is composed almost entirely of the woody part. Attached to the branches are the leaves, the texture of which seems nearly the same as that of the cellular tissue.

Through these parts, vessels are abundantly distributed. Of these, three kinds have been generally distinguished—the general Circulatory vessels, or those which convey the sap, or common juice; the Proper vessels, or those which convey the peculiar juices of the plant after they are formed; and the Spiral vessels, which have usually been supposed to contain air.

The first of these occupy chiefly the middle of plants, rising longitudinally through the roots, but communicating freely with every part, and conveying a juice, generally colourless and insipid. This juice, by its motion in these vessels, and perhaps by elaborations which it suffers in bundles of smaller vessels, termed Utricles, is changed into fluids, of a nature entirely different, which are conveyed by the Proper vessels. The third set, the Spiral vessels, occupy every part of the plant, except the bark, running in a perpendicular direction. As they are generally empty, their office
has

has been supposed to be to absorb and convey air; others have considered them as the absorbent vessels of the plant, drawing in fluids with open mouths, and being generally found empty, from their rigidity preventing them from contracting when cut. — In the leaves of plants, there is an abundant circulation by means of vessels. A large vessel generally runs through the centre of the leaf from the base to the point, which sends out branches that extend to very minute ramifications, that inosculate freely.

As in this general structure of vegetables there is a great similarity to the frame of animals, naturalists have inferred, that both species of organised beings must be endowed with similar powers. At one time indeed, it was attempted to explain all the motions observed in vegetables from mechanical causes: the rise of the sap and the propulsion of the fluids were ascribed to capillary attraction, and the motions of different parts to elasticity of fibres. But such causes are utterly inadequate; and the similarity of these motions to those of animals which are performed for the attainment of similar ends, authorise the conclusion, that they originate in a similar cause,

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The property by which living animal matter is distinguished, and from which the motions of animals result, is *Irritability*,—the property of contracting from certain impressions. Every motion in vegetables demonstrates the existence of a similar power, acting nearly by the same laws. The absorption of external matter, the propulsion of the sap, the numerous secretions which they perform, the motions of their leaves, their susceptibility to the impressions of external agents, light and darkness, heat and cold, moisture and electricity; their growth, and the formation and evolution of the embryo plant,—are phenomena inexplicable on any principle of mechanism, and may be directly deduced from the operation of an irritable principle. This principle too, like that of animals, requires the application of certain stimuli to produce these motions; when these are withdrawn, the functions cease; from their constant or excessive application, a waste of power is produced; and if, by a previous abstraction of usual stimuli, the power has been accumulated, it will be rapidly exhausted by the application of a stimulus moderately strong. The effects of soil, of moisture, of light, and of heat upon plants,—their sleep, germination, efflorescence, fructification and decay,

may, afford many beautiful illustrations of the operation of this principle.

In some respects, the irritability of vegetables differs from that of animals; but these differences are not greater than differences to be found in the respective irritabilities of different orders of animals; nor do they invalidate the conclusion, that plants possess such a power,—a power, not of mere elasticity yielding to impression, but one of contracting on the application of stimuli.

The functions performed by vegetables, subservient to the formation of their chemical products, are Absorption, Perspiration, Respiration, and Secretion.

Absorption is performed by vessels arising from the root, bark, and leaves. These vessels do not take up whatever is presented to them, they select what is proper for the nutrition of the plant; and this, diluted in a large portion of water, forms the common sap.

Perspiration counterbalances absorption; and the quantity of matter thrown out in this way is often

often very great. The perspirable matter seems to be principally water, with at least a very slight impregnation of vegetable matter. The perspiration is increased by a high temperature, by the stimulus of light, and by a dry atmosphere.

Respiration is another function supposed to be performed by plants, and there is no doubt that they are affected by, and produce changes in, the surrounding atmosphere: by means of their leaves they absorb carbonic acid, and while they are exposed to light, they throw out oxygen gas. The sap circulated through the leaf undergoes chemical changes, partly by the action of the vessels, and partly by the chemical agency of light. Part of its water, and perhaps also of the carbonic acid which may have been absorbed, are decomposed; the hydrogen and carbon are retained, and the oxygen is disengaged. When the light is withdrawn, these actions are altered, and carbonic acid is discharged.

Secretion is the function by which the vegetable products are principally formed; the substances taken in, and elaborated in the vessels, being ultimately changed by new combinations of their

their principles. This is performed by a process no doubt analogous to secretion in animals: the utricles are supposed to be the glands, or secreting organs.

Circulation cannot properly be said to exist in the vegetable system; as there is no point from which a fluid is propelled and to which it returns. It seems probable, however, that a kind of circulation is carried on in the leaves. Dr. Darwin supposes, that the large vessel passing through the middle of the leaf conveys sap, and performs the office of a pulmonary artery, by distributing the fluid over an extensive surface exposed to the atmosphere. From its extremities, the fluid, changed in its composition, returns by vessels running along the under surface, and these, uniting at the foot stalk, pass perhaps to the utricles, or to other parts of the plant.

The food of plants, or the supply of matter necessary for their growth and the formation of their various products, is derived from the air and soil. It consists of water more or less loaded with vegetable and animal matter, and several gases, which this water holds dissolved, or the atmosphere

sphere affords. The operation of several other substances is in general requisite to prepare these substances for absorption; and the agency of light, partly as a stimulus, partly as a chemical power, is indispensable in the process of vegetation.

The utility of the soil consists principally in affording a support to the growing vegetable, and in conveying to it water more or less pure. It has been sufficiently demonstrated, that little of the earth itself is absorbed. From experiment, it has been shewn, that the earth in which a plant grows suffers scarcely any diminution of weight, and that many plants may be made to grow in pure water alone. Parasitic plants, and those which grow upon stones or rocks, can derive no nourishment from the earth; and the analysis of vegetable matter has shewn, that their solid parts and all their products are composed of principles entirely different from the matter of which the soil consists. It has therefore been concluded, that air and water furnish a principal part of the food of every vegetable; and that many can live and grow upon these alone. Objections have
been

been urged against this conclusion ; but they are formed upon experiments, the accuracy of which may be justly questioned.

Water enters largely into the composition of every kind of vegetable ; but it further proves nutritious to vegetables, by being decomposed in their vessels. Hydrogen is perhaps the most abundant element of the greater part of the vegetable products ; and in plants subsisting on water and air, there is no source whence it can be derived, but from the decomposition of the former. The hydrogen is retained, part of the oxygen is also probably fixed in the vegetable, though the greater part of it appears to be thrown out by the leaves.

From the atmosphere, plants, it has been proved, absorb carbonic acid by their leaves, and this may likewise be conveyed to them by the water absorbed by their roots ; the carbonic acid being heavier than atmospheric air, and therefore descending to the soil. Art can scarcely effect the decomposition of this acid ; but in the vessels of vegetables, where the most complicated affinities

are brought into play, and under various modifying circumstances, such a decomposition is sufficiently possible. It is the only evident source whence the carbon contained in those vegetables which grow in water and air can be derived; and it has been found, that plants supplied with water impregnated with carbonic acid, afford more oxygen than when pure water is afforded to them.

As vegetables absorb hydrogen gas when confined in it, it is probable they may absorb the hydrogen occasionally passing through the atmosphere from the decomposition of vegetable and animal matter. The influence of the azot of the air seems to be inconsiderable: little of it probably is absorbed, as it scarcely enters into the composition of their products. The absorption of oxygen, it is reasonable to conclude, is equally inconsiderable, as more of this element is afforded by the decompositions going on in the vegetable substances, than is necessary to be retained. Oxygen, however, especially when applied to the roots, by having been absorbed by water, appears to be useful as a stimulus to the plant; and hence in part is explained the fertilising influence of dews.

In

In the process by which these substances are rendered subservient to the nutrition of the vegetable, light acts an important part. When it is excluded, the usual products are no longer formed; no oxygen gas is discharged; but that portion of carbonic acid which is absorbed, seems to be merely thrown out unchanged. It is not by the heat which it excites that it renders vegetation vigorous, since an equal heat, applied by any other means, has not the same effect. It may act partly by its stimulus, exciting the vessel to stronger action; but neither can it be solely by this mode of operation that it proves useful, since the substitution of other powerful stimuli, ought, for a time at least, and to a certain extent, to be productive of the same phenomena. It therefore acts as a chemical power, probably by exerting an attraction either to the oxygen of the water and carbonic acid, or to their carbon and hydrogen, and thus promoting the attractions of the vegetable matter already existing in the sap, or composing the vessels — by which joint affinities, these compounds are decomposed.

Such is the most simple view of the theory of vegetation. The vegetable, by its own powers,
assisted

assisted by the agency of light, decomposes part of the water and carbonic acid which it receives; the carbon and hydrogen of these, with part of the oxygen, are expended in the formation of the vegetable products, while the superfluous oxygen is thrown out: hydrogen is also, perhaps, to a certain extent absorbed, with a small portion of azot; and, either from combinations of these elements, or, what is more probable, from the soil, by the medium of the water absorbed, may be derived the small portion of the saline, earthy, and metallic substances which are found in vegetable matter.

But there are many vegetables which require other nutritious substances for their support and growth than water and these gases. This is proved by the most familiar facts. Many vegetables flourish only in certain soils; those which require a rich soil, vegetate feebly when made to grow in a poorer; and many of them soon exhaust the soil, so that it requires to be renewed by artificial means. It has likewise been ascertained by experiment, that even those plants that are capable of growing when supplied with water and air alone, are still more vigorous when placed

placed in a soil which affords matter more directly nutritious.

Of the substances which contribute to the growth of vegetables, the most necessary is decomposing vegetable and animal matter. It furnishes matter already assimilated to the nature of the vegetable, and it constitutes what is termed the richness, or fertility, of a soil. The water present dissolves the mucilaginous and extractive matter, and is absorbed by the roots; and during the decomposition or slow putrefaction, various gases, particularly carbonic acid and carbonated hydrogen, are disengaged, which are probably taken up by the absorbents in the roots of the plant, and afford directly the elements of which the vegetable products are formed.

Besides this species of manure, which is the only one directly nutritious, there are others which are scarcely less useful, by promoting the decomposition of the vegetable or animal matter which it contains.

The action of lime is to be explained on this principle. Though various indirect advantages are derived from it in improving the soil, and
though

though it acts as a stimulus to the plant; its principal utility seems to depend on its hastening the decomposition of the vegetable matter, by which the different gases capable of contributing to the nourishment of the plant are more abundantly supplied. Hence it is useful principally in these soils which contain much vegetable and animal matter; and when this is exhausted, the lime is less useful till the earth is again manured. In promoting this decomposition, it may act by combining with one or other of the component parts of the vegetable matter, and thus breaking the order of their attractions; or perhaps, by a disposing affinity, arising from the strong attraction it has to carbonic acid.

The last class of substances which promote vegetation are those which act as stimulants to the vegetable. Light, though acting as a chemical power, likewise stimulates the vessels of plants to stronger action, and hence renders the exercise of their functions more vigorous. Heat is not a less powerful stimulant, and is of all others, perhaps, the most necessary to vegetation. Oxygen contributes both to the commencement and progress of vegetation, partly by its chemical agency, and partly by its

its stimulant operation; and several of the most important practices of agriculture are founded on the necessity of this application of oxygen, especially to enable vegetation to commence.

Having stated the various circumstances influencing vegetation, the following may be given as a general view of the changes which take place in this process. A seed, which is the origin of every vegetable, consists of two principal parts—the Germ, or small bud, which appears to be the part endowed with life, the embryo of the plant; and the Seed Lobes which are attached to it.—When placed in a situation favourable to vegetation, it absorbs moisture, becomes soft, and swells; oxygen is abstracted from the air in contact with it, and combines with, or acts in such a manner upon the seed lobes, as to change them to a substance of a saccharine nature, which serves for the nutrition of the germ. Its growth begins; the function of absorption by which its nourishment is to be continued is established; and the functions of perspiration and respiration soon commence. Water, more or less impregnated with matter from the soil, is taken up by the roots; carbonic acid and other gases are received from the

the surrounding atmosphere, or from the decomposition of the matters contained in the earth. The mixture of these substances forms the sap, which, in its progress through the vegetable, is more or less mixed with its other juices, and changed by the action of its vessels. It is brought to the leaves, and circulated through them, so as to present a very extensive surface covered with a very thin membrane to the atmospheric air. A great part of its water is thrown out by perspiration; carbonic acid is probably absorbed; and upon this sap the light acts by its chemical agency, as well as by its stimulating power, promoting the decomposition of part of the water and carbonic acid. The greater part of the oxygen, let loose by these decompositions, is thrown out by the leaves; the sap, with the increased proportion of carbon and hydrogen, is conveyed to the secreting organs of the vegetable, or is further elaborated by the vessels, so as to form new combinations, adapted to the various purposes of the vegetable economy.

In the various stages of the growth of the vegetable, and in different plants, the sap, or common juice from which these products are formed, varies

varies in its composition. In the analysis of it by Vauquelin and Deyeux, it was found to contain, besides a portion of vegetable matter, sugar, tanin, gallic acid, and acetates of potash, lime, and argil, and carbonat of lime. Scarcely any conclusion can be drawn from these analyses, as it is difficult to obtain the sap entirely free from the proper juices of the plant.

CHAP. II.

OF THE PROXIMATE PRINCIPLES OF VEGETABLES.

THE Analysis of vegetables is of two kinds. We are able, by an immediate analysis, to resolve their products into certain principles, distinguished from each other by peculiar chemical qualities; and by a further analysis, we can resolve these principles into simple elements, principally into carbon, hydrogen, and oxygen, united in some of them with azot and lime. The former are termed the Proximate, the latter the Ultimate principles of vegetable matter.

The proximate principles exist in the different parts of vegetables, and in their various products, in a state of mixture or combination, and are separated from each other, so as to be obtained in
distinct

distinct states of existence, by means founded on their chemical properties, or on their relations to other chemical agents. This forms the *immediate vegetable analysis*. Suppose, for example, that the composition of the bark of a certain vegetable is to be ascertained — If it is macerated in water, the water acquires taste, colour, and other properties,—a proof that something has been dissolved. If it is heated with the water in close vessels, a portion distils over, which has odour and pungency; and thus some volatile principle is obtained. If the remaining matter is digested in alcohol, a substance is still extracted, which had resisted the action of the water and of heat. By repeated experiments of this kind, nothing is left but the woody fibre of the bark.

In this manner a number of distinct substances may be obtained; and of these, variously mixed and combined, the vegetable productions are formed. It is to these proximate principles chiefly that the attention of the chemist is directed, in examining the products of the vegetable kingdom. To examine every individual vegetable substance, would be an endless labour; and in a chemical point of view, it would be one comparatively

tively useless, as many of them would be found so much alike, that no discrimination of them as chemical agents could be established. They are, therefore, considered in a more general point of view. The different substances existing in vegetables which can be separated from each other, and distinguished by peculiar properties, form so many genera; and to these the investigations of chemistry are confined.

The *ultimate analysis* of vegetables is merely the decomposition of their proximate principles. It is effected in various modes.

When any vegetable matter is exposed to a temperature superior to 212° , its water is first expelled, the decomposition of its principles then commences, and its elements enter into new combinations. A coloured empyreumatic oil distils over, accompanied and followed by an acid liquor: carbonic acid and carbonated hydrogen gases are discharged, and a quantity of charcoal remains, consisting of carbonic acid and minute portions of salts, earths, and metals, which the vegetable matter had contained. These products are not those which existed in the vegetable matter, but are
new

new combinations, arising from the decomposition of the proximate principles, and the union of their elements in new modes and proportions. The oil results from the union of part of the hydrogen with part of the carbon of these principles; the acid, from the combination of another portion of carbon and hydrogen with oxygen; the carbonic acid and carbonated hydrogen are similar products; and the remaining charcoal arises from the excess of carbon, not spent in the formation of these new compounds.

From such an analysis, little is learned of the matter subjected to it; for although the products can be collected, and their composition by a further analysis ascertained, yet experiments of this kind are liable to sources of error nearly inappreciable. From slight variations in the state of the matter analysed, with respect to humidity, or from still slighter variations of temperature in conducting the experiment, important differences in the results will be produced; and we are likewise unable to ascertain what quantities of the products of the analysis have pre-existed in the vegetable matter, or have been actually formed. We acquire, therefore, only some general information.

mation. If much acid has been afforded by the analysis, we conclude, that the matter analysed has contained a large proportion of oxygen, as that matter is indispensable for the production of acids. If much oil has been obtained, we conclude, by a similar mode of reasoning, that hydrogen has been an abundant element of the matter analysed. From the production of ammonia or prussic acid, we infer the existence of azot : from the quantity of charcoal, we draw some conclusion as to the quantity of carbon existing in the vegetable ; and by burning this charcoal, we discover the quantities and kinds of earth and metal which it has contained.

Sometimes vegetable matters are analysed by heating them in contact with atmospheric air, so as to excite combustion ; and from the products, determining the nature and proportions of the constituent principles. Certain principles can likewise be analysed by subjecting them to spontaneous decomposition, as saccharine matter, for example, by the process of fermentation : and lastly, vegetable analysis may in some cases be effected by the agency of the nitric or oxygenated muriatic acid, which produces oxygenation of the
vegetable

vegetable matter, and by the product indicates the principles of which it has been formed.

The proximate principles of vegetables, or those compounds of their ultimate principles which, by mixture or combination, form every kind of vegetable matter, have been reduced to the following genera : Mucilage or Gum, Fecula, Saccharine matter, Gluten, Albumen, Fixed Oil, Volatile Oil, Camphor, Wax, Refin, Extract, Cautchouc, Acids, Tannin, Colouring Matter, Ligneous Fibre.

Seet. I. — — MUCILAGE, or GUM.

THIS is one of the most abundant proximate principles of vegetable matter, and it seems to be the first product of the changes which the sap suffers from the action of the vessels. It is found in all young plants, in their roots, stalks and leaves, and particularly in their seeds ; and it is often present in such large quantity in their vessels as to be discharged by spontaneous exudation. It is thus
obtained

obtained in its purest state. It is inodorous and insipid, solid and brittle; neither fusible nor volatile; nor is it inflammable, in the strict sense of the term. It is soluble in water in every proportion, forming a thick viscid solution, and is insoluble in alcohol or oil. Triturated with oils, it suspends them in water.

Gum is oxydated by different acids. The nitric, by imparting to it oxygen, converts it into oxalic,---the oxygenated muriatic, into nitric acid.

Gum cannot by any management be converted into saccharine matter, or be made to pass into the vinous fermentation: by this it is distinguished from some other principles which it otherwise resembles. The watery solution of it becomes sour on keeping, from its principles entering into new combinations, and forming the acid termed Pyromucous.

According to the analysis of gum by Mr. Cruickshank, it affords, when exposed to heat in close vessels, pyromucous acid, carbonic acid, hydro-carbonate gas, and ammonia; the residuum being

being charcoal containing lime. Its constituent principles are therefore oxygen, hydrogen, carbon, azot, and lime; and it seems to be from the addition of the two latter principles, that several of the peculiarities in its chemical properties arise.

The purest gums are, the Gum-Arabic, the produce of the *mimosa nilotica*; and the Tragacanth, which exudes from the *astragalus tragacantha*. Gums, less pure, are likewise obtained from the cherry and plumb trees of this country. There seems to be little foundation for the distinction which has been made between gum and mucilage.

Gum is principally used in pharmacy, to render oils and resin miscible with water. In the arts, it is employed on account of the adhesive quality of its watery solution.

Sect. II. — — — *FECULA.*

THE term *Fecula*, or *Starch*, is appropriated to a particular vegetable proximate principle, which forms the chief part of the nutritive grains and roots. It is extracted from them by beating or kneading them with a large portion of water. The soluble matters are dissolved, and the water is at the same time rendered milky from the diffusion in it of a white powder, which gradually subsides, and may be dried. It can thus be obtained from wheat, rye, or other seeds, and from the roots and stems of a number of plants. As first obtained, it is frequently grey; but it may be rendered white, by allowing the liquor which has been used to extract it to become sour from the fermentation of the saccharine matter it contains, and keeping this acid liquor over it for some time.

Fecula is in the form of a light white powder, insipid, inodorous, and soft to the touch. It is perfectly insoluble in cold water; but it dissolves completely

completely in hot water, and forms a gelatinous solution. This jelly, when dried, is still insoluble in cold, and soluble in hot water. By this property, fecula is clearly distinguished from gum, which is soluble in water at every temperature. It is likewise distinguished by being convertible into saccharine matter by a peculiar process. It is insoluble in alcohol.

Fecula is dissolved and oxydated by several of the acids. By nitric acid it is converted into oxalic and malic acids. Exposed to heat in close vessels, it affords a large quantity of an acid liquor, with carbonic acid and hydro-carbon, leaving a residuum of charcoal. Heated in contact with the air, it becomes black, and is consumed without flame. From these analyses of it, fecula appears to be a ternary compound of carbon, hydrogen, and oxygen.

SECT. III.

SUGAR.

SACCHARINE matter is very generally mixed with the fecula in the feeds and roots of plants; and it exists in still larger quantity as one of the proper or secreted juices of the vegetable. The juice of the sugar cane affords the greater part of the sugar of commerce, though it is likewise obtained in large quantity from the sugar maple, from the beet, parsnip, and various other roots. The general process for obtaining sugar pure, is to express the saccharine juice, and add to it a quantity of lime to neutralise the organic acid present, which prevents the concretion of the sugar. By due evaporation, it is made to concrete; it is purified by boiling it with lime water and blood,—the latter coagulating and entangling many of the impurities. The liquor, after the necessary boiling, is run into conical molds of clay, which absorbs the superfluous moisture, and the concrete sugar is dried in a stove.

Fecula

Fecula is likewise convertible into sugar. This constitutes the process of malting. The grain containing the fecula is bruised, macerated in water, and exposed to the air at a temperature between 60° and 70° , vegetation commences, oxygen is absorbed, carbonic acid discharged, and the fecula is found to be entirely converted into saccharine matter.

Sugar has a pure sweet taste, accompanied by no flavour; its colour is white; it is soluble in an equal weight of water at 60° , and in a less quantity of boiling water; its solution can be crystallized; its crystals are prismatic, hard, and considerably transparent. It is likewise soluble in alcohol; and this solution affords crystals when part of the solvent is evaporated.

Sugar exposed to heat is soon blackened, and burns to a coal; and if the heat be strong, this combustion is attended with flame. Heated in close vessels, it yields a large quantity of an acid, an empyreumatic oil, carbonic acid, and carbonated hydrogen; the residuum being charcoal. Its constituent principles, therefore, are hydrogen, carbon, and oxygen. The proportions of these, according

according to Lavoifier, are 8 of the first, 28 of the second, and 64 of the third.

From the differences in the composition of gum, fecula, and sugar, we can trace, though perhaps in an imperfect manner, their successive formation in the process of vegetation. The sap consists of vegetable matter, and of several salts which have lime for their basis: gum, the primary product perhaps of the general process, is composed of carbon, hydrogen, and oxygen, the common constituents of vegetable matter, with azot and lime: by a further elaboration, the two latter principles are abstracted, and thus fecula is formed: and this again, by a change in the proportions of its principles, and particularly by an addition of oxygen, is converted into sugar. The formation of sugar in the vegetable system takes place principally in the parts secluded from light, as in the vessels of the root and stem; and it is remarked by several chemists, particularly by Achard, that the exclusion of light greatly favours its production. This may be explained from the fact, that the exclusion of light with respect to a growing vegetable always produces in it an accumulation of oxygen, and of course, according to this view

view of the subject, will favour the conversion of fecula into sugar. An apparently contradictory fact is likewise related by Achard ; that although the exclusion of light increases the production of sugar in the body of the plant, exposure to light favours its formation in the fruit,—a fact indeed sufficiently exemplified in the maturation of fruits. This, however, still confirms the present explanation. In the fruit, the sugar is formed, not from fecula, but from an acid juice ; and this conversion seems to be effected, as we might *a priori* infer, by an abstraction of oxygen.

When sugar is oxydated, it is converted into the oxalic acid. This oxydation is most easily effected, by distilling from it six parts of nitric acid.

Sugar, dissolved in water, and placed in a proper temperature, undergoes a change in its composition, and is converted into ardent spirit. This forms the process termed Fermentation, which is afterwards to be considered.

HONEY is another vegetable product similar to sugar. It is formed in the flowers of the plant :

it

it is always exposed to the air, and frequently by very complicated arrangements ; and has been supposed designed to receive the pollen from the male parts, as its secretion diminishes or ceases when the fecundation is completed.

SECT. IV. — — — GLUTEN. ALBUMEN.

ALONG with the fecula and saccharine matter, which compose the principal part of the nutritive grains and roots, other two principles, gluten and albumen, exist.

GLUTEN.—When the flour of wheat is washed with water, the soluble matter is dissolved, the fecula is suspended, and there remains a viscous, fibrous, and very elastic mass, which, from its similarity to an animal principle named Gluten, is termed Vegetable Gluten. It is insipid, and of a greyish colour—is insoluble in water, and is dissolved in very small quantity only by alcohol. The fulphuric, muriatic, and acetous acids dissolve it, as do the alkalis, the alkaline solutions being decomposed.

composed by the acids, and the acid solutions by the alkalis. Nitric acid decomposes gluten, and disengages from it a considerable portion of azotic gas, and forms its remaining elements into oxalic acid.

Gluten putrifies when exposed to a moist atmosphere. When decomposed by heat, it affords a large quantity of ammonia with carbonic acid, and an empyreumatic oil. It therefore differs from the other vegetable principles in containing a large proportion of azot.

ALBUMEN.—This principle, which is likewise similar to an animal principle of the same name, is combined with gluten in the nutritive grain. It is dissolved by the water, by which the flour is decomposed, and separates in light flakes when this water is heated. It is soluble in cold water, but is coagulated by heat, or by the addition of alcohol: it dissolves in the alkalis; is liable to putrefaction; and affords ammonia when decomposed by heat.

The mixture of gluten and albumen with the fecula and sugar, in many of those vegetables which are used as food, render them more nutritious, as they are already of an animal nature, and contain those elements of which, with carbon, hydrogen, and oxygen, animal matter is formed. Hence the superiority of wheat as an article of nourishment, to any other vegetable substance, the gluten it contains being in much larger proportion than in any other. The presence of gluten in wheat likewise renders the bread formed of it of a superior quality. The flour of other grains forms solid friable pastes; while the flour of wheat, when moistened, forms a mass more ductile and porous; owing probably to the gluten combining with the water, and forming an elastic paste, through which the fecula is intermixed. The slight degree of fermentation, which is necessary to make good bread,—raising it, as it is termed, or rendering it light and porous,—depends on the portion of saccharine matter the farina contains.

See.

Sect. V. — — — *FIXED OIL.*

Two kinds of oil, the Expressed, or Fixed, and the Essential, or Volatile, are found in vegetables, which have certain common properties,—unctuosity and inflammability: but they likewise possess peculiar properties, by which they are distinguished as separate classes.

Fixed oils are generally contained in the seeds and fruits of those vegetables of which they are the products, and only at the period of maturity. They are extracted by mechanical pressure,—whence they are named Expressed oils,—or by decoction with water. They are frequently impregnated with the mucilaginous or extractive matter of the vegetable, whence they acquire colour, odour, and taste: but when pure, they are insipid and inodorous; they are lighter than water; their consistence is thick and unctuous, and some of them are even concrete. Those that are fluid congeal on exposure to moderate cold,

Expressed

Expressed oil is incapable of combining with water, and is equally insoluble in alcohol.

Expressed oil cannot be volatilised by heat unchanged. At temperatures below 600° of Fahrenheit, they remain fixed; nearly at that temperature, they are converted into vapour; but the oil thus condensed is found altered in its properties; it has lost its mildness, and is become more limpid and volatile, a portion of carbon being likewise deposited. Transmitted through an ignited tube, it is converted into carbonic acid and carbonated hydrogen.

Expressed oil, exposed to a warm atmosphere, gradually acquires a sharp taste and disagreeable smell, and becomes thick. This change, termed Rancidity, is owing to absorption of oxygen; and hence it is still more rapid when the oil is exposed to oxygen gas.

At the temperature of ignition, at which it is converted into vapour, oil burns in atmospheric air; a large quantity of light and caloric is extricated by its combustion. When the access of the air to the vapour of the oil is not complete, it
burns

burns with a black smoke ; and a quantity of carbonaceous matter, which has escaped the combustion, is deposited. Hence the utility of a slender wick, which draws up the oil by capillary attraction, and, when kindled, converts it into vapour; and still more of a hollow wick, through which an internal circulation of air is established.

The products of the combustion of oil are water and carbonic acid. 100 Parts produce 140 of the former and 281 of the latter, combining with 321 of oxygen; whence Lavoisier inferred, that oil consists of 79 parts of carbon and 21 of hydrogen. This conclusion, however, was founded on the supposition, that common charcoal is the simple base of carbonic acid, and requires only 72 parts of oxygen to saturate 28. As it is an oxyd containing even a considerable proportion of oxygen, the proportion of pure carbon in expressed oil must be less than the above, and oxygen must likewise be admitted into its composition.

Expressed oil is oxydated by a number of the acids. Sulphuric acid soon renders it black; the oxygen of the acid attracting part of the hydrogen of the oil, and thus causing the deposition
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of part of the carbon. Nitric acid in the cold thickens these oils; at a high temperature, its action is more violent: and the oils which have been expressed by the assistance of heat, so as to be rendered empyreumatic, are even inflamed by this acid. The muriatic exerts upon them scarcely any action: they are thickened, or even rendered concrete, by the oxygenated muriatic.

Expressed oil combines with the alkalis, and forms soap. If one part of oil be mixed with half its weight of a strong solution of pure potash or soda, a thick white mass is formed, which can be diffused in water forming a milky-like mixture. If the oil and the alkaline solution be boiled together, a more intimate combination is effected, and a solid compound is obtained. The soap thus prepared differs according to the purity of the ingredients. Common soap is made of animal oil, or fat, with impure potash. The cleansing property of this compound depends on the alkali; but it is preferable to the pure alkali, because it acts less as a solvent on the cloth, and gives it besides a softness and smoothness.

Soap

Soap is soluble in water, the solution being opaque, from the intermixture of particles of uncombined oil. It is also soluble in alcohol. It is decomposed by all the acids, and by the greater number of the earthy and metallic salts. Hence spring waters often decompose it, from the quantity of sulphat of lime they contain. The oil separated by these decompositions is soluble in alcohol. Soap, decomposed by heat, affords water, empyreumatic oil, and ammonia.

Ammonia forms with expressed oil a less intimate combination than the fixed oils do, as heat cannot be employed to favour the combination. The addition of a small quantity of it is employed in pharmacy to suspend oil in water.

The combinations of expressed oil with the earths and metallic oxyds may be obtained, by adding their salts to a solution of soap, when a double decomposition takes place. These compounds have a saponaceous quality.

Expressed oil, when boiled on sulphur, combines with it, and forms a compound of an extremely foetid smell and acrid taste. It likewise
dissolves

dissolves phosphorus. It combines with several of the other vegetable principles, with gum, resin, &c. Triturated with mucilage, it forms a milky mixture,—a mode of suspending oil in water which is sometimes employed in pharmacy.

Sect. VI.

— — VOLATILE OIL.

VOLATILE, or Essential, Oil is contained in the flowers, fruits, leaves, wood, or bark, of many vegetables, generally in inconsiderable quantity, the proportion varying, however, according to the age or vigour of the plant. The oil sometimes exists in distinct vesicles, and may therefore be obtained by expression. But the usual method to procure an essential oil, is to subject the vegetable matter containing it to distillation along with water. The oil is volatilised with the aqueous vapour, and is easily condensed: a small portion of the oil is retained in solution by the water; but the greater part of it separates, and may be obtained pure from the difference in their specific gravity.

Essential

Essential oil is odorous, rapid, and generally pungent. The taste and smell of the oils obtained from different vegetables are very different; and they likewise produce different effects on the animal system. They are generally lighter than water; but some have a greater specific gravity. They are also usually fluid; and remain so even at a low temperature; but others congeal even at a very moderate degree of cold, and some are naturally concrete.

Essential oil is soluble in water in minute proportion. The water acquires its taste and flavour. This impregnation is commonly obtained by distillation; the distilled waters of pharmacy being thus formed.

It is much more soluble in alcohol: some of these oils, however, are less so than others. By distillations of alcohol, from vegetables containing essential oils, distilled spirits are formed.

Essential oils are volatilised by a very moderately increased temperature. Exposed to a higher

heat, near to that of ignition, they suffer partial decomposition.

Exposed to atmospheric air, they lose their smell, are thickened, and become concrete ; frequently depositing at the same time crystals of an acid nature. These changes are owing to the absorption of oxygen.

When heated in contact with atmospheric air, they are more easily inflamed than the expressed oils, and they yield more water by their combustion. Hence they differ from the fixed oils in containing a larger proportion of hydrogen, to which, probably, their greater volatility and inflammability are owing.

The essential oils are oxydated by the acids. Sulphuric acid renders them black ; nitric acid inflames them rapidly, especially if mixed with half its weight of sulphuric acid ; the diluted nitric acid oxydates the oil, only so far as to convert it into a matter of a resinous nature ; the oxygenated muriatic acid produces in it a similar change.

Essential

Essential oil combines with difficulty with the fixed alkalis: the combination can indeed only be effected by long trituration: the compound is slightly saponaceous. Liquid ammonia distilled with the oil combines with it, but very sparingly.

These oils dissolve sulphur and phosphorus. They unite with mucilage or sugar; and by the medium of either, may be suspended in water. They dissolve resin, camphor, and several other vegetable principles.

Sept. VII. — — — CAMPHOR,

THIS principle exists in comparatively few vegetables. For use, it is extracted from the *Laurus Camphora*, a native of Japan; the wood of the trunk and branches being exposed to a moderate heat in close vessels, by which the camphor is sublimed. It is at first impure, but is purified by a second sublimation. This substance is likewise deposited

deposited from several essential oils when they are long kept.

Camphor is solid and tenacious, of a white colour, and semi-transparent; having a strong fragrant odour, and a very pungent taste. It is so volatile, that it quickly loses weight when exposed to the atmosphere; and at a very moderately increased temperature it sublimes unchanged. It is scarcely soluble in water, but is abundantly dissolved by alcohol and the essential and expressed oils.

When camphor is mixed with any substance which opposes its volatilisation, as clay, it is decomposed by heat; a volatile oil, pungent and fragrant, having all the properties of an essential oil, distils over; small quantities of hydro-carbonate and carbonic acid gases, with camphoric acid, are disengaged; and there remains a portion of charcoal. From this decomposition, it may be concluded, that camphor is similar in its composition to essential oil, and differs from that principle in containing a larger proportion of carbon.

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The acid termed Camphoric, obtained by this decomposition, is absorbed by the water placed in the receiver, and by evaporation may be made to crystallize. When pure, it has little or no odour; its taste is slightly acid, and it reddens the vegetable colours. It is very volatile. It resembles another vegetable acid, the benzoic, but is easily distinguished from it by its great solubility in cold water. The salts it forms with the alkalis and earths are termed Camphorats.

Camphor is highly inflammable. Camphoric and carbonic acids are produced by its combustion, and carbon is deposited.

It is soluble in the acids. The sulphuric acid, and the muriatic, fluoric, and sulphureous acid gases dissolve it without changing it. The nitric acid likewise dissolves it; and when the solution stands for some time, an oily-like fluid floats upon its surface, which is decomposed by water, camphor being precipitated. If nitric acid be distilled eight or ten times from camphor, the latter is converted into camphoric acid.

Camphor

Camphor does not combine with the alkalis. Triturated with magnesia, it is rendered more soluble in water.

SECT. VIII.

WAX.

WAX seems to have the same relation to the fixed, that camphor has to the volatile oils. It is produced on the antheræ of flowers, whence it is collected by the bee; it is yielded by the fruit and leaves, and is sometimes contained in their juices. It is very fusible; by a high heat it is decomposed; a thick empyreumatic oil, with an acid liquor, being the products; the residuum is charcoal. It is inflammable: the products of its combustion are water and carbonic acid; and from the quantities of these, Lavoisier calculated that it consists of 13 parts of carbon and 2 of hydrogen.

SECT.

Sect. IX.

RESIN.

THIS principle is often combined or intermixed with the other vegetable principles, especially with gum. When obtained pure and unmixed, by exudation from certain plants, it is concrete, insoluble in water, but entirely soluble in alcohol, ether, and oils. It is fused at a heat not exceeding that of boiling water: by a strong heat it is decomposed; an empyreumatic oil, an acid, hydro-carbonate and carbonic acid gases, being the products, charcoal the residuum. Heated in contact with atmospheric air, it burns; the products of the combustion being carbonic acid and water. The ultimate elements of resin, therefore, are carbon, hydrogen, and oxygen. It is in the presence of a larger proportion of the last, that it differs from essential oil.

At the common temperature of the atmosphere, resin suffers no alteration; neither is it altered by moisture. Hence solutions of resins in alcohol or
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in oils are employed as varnishes to preserve other substances uninjured.

The different resins have generally taste and flavour; though when pure, as in copal or sandarach, they are nearly insipid and inodorous.— Their effects on the animal system are sometimes considerable; and the activity of many vegetable remedies depends on their resinous part. As the different resins have the same chemical properties, it is unnecessary to notice them.

In certain vegetables, there exists a natural combination of resin with essential oil, forming a thick fluid, odorous and pungent, termed Balsam. These balsams, by distillation, yield a quantity of essential oil, a resinous matter remaining. They likewise generally contain a portion of the vegetable acid termed Benzoic.

There exists in many vegetables a combination of gum and resin, forming a proximate principle termed Gum Resin. It appears to be, not a mere mixture, but a more intimate combination of these principles. The proportions in which they are united are various; but in general

ral they are such, that a mixture of equal parts of alcohol and water is capable of dissolving the gum resin.

Sect. X.

— — — **EXTRACT.**

A VEGETABLE substance which, in several of its properties, bears a resemblance to gum resin, has been distinguished by the name of Extract, or Extractive Matter. Its principal characters are, that it is equally soluble in water and in alcohol, thus differing from resin, gum, and gum resin; and that it is insoluble in sulphuric ether. It likewise absorbs oxygen when exposed to the atmosphere, and forms an insipid substance no longer soluble in water. At the temperature of boiling water, this change proceeds with great rapidity; and it is from this oxydation, that the activity of many vegetable remedies is lessened or destroyed by long decoction with water. By oxygenated muriatic acid, extract is converted into a concrete substance, of a yellow colour, insoluble in water. By distillation, it affords an empyreumatic

tic acid and oil, and a small quantity of ammonia.

The extractive matter is obtained, by maceration in water, from those vegetables in which it exists: by subsequent evaporation, it forms what are termed their Extracts. Respecting the nature and mode of existence of this principle, however, there is some obscurity; and it is still doubtful, from various causes, whether what has been termed Extractive Matter is a principle of uniform composition and chemical properties, or whether it is not rather a mixture or combination of some of the other proximate principles, generally of the gummy and resinous parts, with some saline substances.

Sect. XI.

— — ELASTIC GUM.

THE names of Caoutchouc and Elastic Gum have been applied to a particular vegetable production, the juice of a tree, a native of South America, and which has likewise been obtained from several East-Indian plants. It is obtained from incisions
made

made in the bark—is at first thick and milky, and becomes concrete on exposure to the air, from absorption of oxygen.

The distinguishing property of this substance is its great elasticity : it can be stretched to a considerable extent without breaking, and it immediately again contracts. It is softened, but not dissolved by water : it is likewise insoluble in alcohol, but is dissolved by the ethers, the fixed and essential oils, and rectified petroleum. It is not acted on by the alkalis. Sulphuric and nitric acid alter it, by communicating to it oxygen.

Caoutchouc is softened, and loses its elasticity, by heat. Heated in close vessels, it affords carbonic acid, carbonated hydrogen, ammonia, and an empyreumatic oil. Its elements are therefore carbon, hydrogen, oxygen, and azot.

Sect.

Sect. XII. — — VEGETABLE ACIDS,

THERE exist in the juices of many plants, especially at certain periods of their vegetation; peculiar acids; and the same or other acids are likewise found combined with some of the proximate vegetable principles, or united with alkalis and earths, forming what have been termed the Essential Salts of Plants. Of these native vegetable acids, there are seven, distinguished from each other by certain properties — the Citric, Malic, Oxalic, Gallic, Benzoic, Tartarous, and Acetous. They have all a compound base of carbon and hydrogen, and differ from each other principally in the proportions of their principles: hence the greater number of them are convertible into each other. The oxalic seems to be the one most highly oxygenated, and into which the others may be changed.

CITRIC ACID.

Citric Acid is found in the lemon, the tamarind, and many other four fruits ; and is obtained by expression : the mucilaginous matter is precipitated by alcohol, which is afterwards evaporated ; or the citric acid is saturated with lime, and the citrat of lime is decomposed by adding half its weight of sulphuric acid, diluted with six parts of water. The pure acid can be obtained in a crystalline form : the crystals are very soluble in water, and possess the general acid properties. It combines with the alkalis and earths, and its attractions are stronger to the latter than to the former.

Citric acid and any of its salts are decomposed by heat ; the products being carbonated hydrogen, carbonic acid, and an empyreumatic acid, with a residuum of charcoal. It is convertible, not into oxalic, but partly into carbonic, partly into acetic acid, by further oxygenation.

MALIC ACID.

This acid abounds in the juice of unripe fruits, particularly in apples, whence its name. It is obtained pure, by triturating the juice with lime, and decomposing the compound by sulphuric acid. To whatever length the evaporation of the solution of the malic acid may be carried, it does not crystallize. With the alkalis it affords deliquescent salts; with lime, one that is crystallizable. It is decomposed by heat; and as it gives more carbonic acid than the citric, it has been concluded, that it contains a larger quantity of oxygen. It is changed into oxalic acid by the action of nitric acid.

OXALIC ACID.

This acid exists in the different species of sorrel, and in several other vegetables. The expressed juice, by standing sufficiently long, or by being boiled with the white of an egg, is freed from its impurities, and deposits crystals, which are the acidulous oxalat of potash. Their taste is sour; and they require

quire a considerable quantity of water for their solution. The pure acid is obtained by saturating the excess of acid by ammonia, and adding to this triple salt nitrate of barytes; oxalate of barytes is formed, which is decomposed by sulphuric acid.

This acid is likewise obtained by the oxygenation of sugar; eight parts of nitric acid being distilled from one of white sugar, and the distillation being continued till the remaining fluid is of the consistence of a syrup. This deposits crystals of oxalic acid on cooling. The change in this case is owing to the sugar being deprived of part of its carbon, and receiving an additional proportion of oxygen.

Oxalic acid has a very acid taste; is soluble in two parts of cold, and in an equal part of boiling water. Exposed to heat, it is resolved into an acid liquor, carbonic acid, and carbonated hydrogen. It contains more oxygen than the other vegetable acids.

Oxalic acid combines with the alkalis and earths; its attractions being stronger to the latter than to the former. It is particularly distinguished
ed

ed by its strong attraction to lime, which is superior to that of any other acid.

TARTAROUS ACID.

This acid, as it exists in vegetables, is combined with potash, forming the acidulous tartarite of potash. This salt, known to chemists by the names of Tartar, Purified Tartar, is contained in the tamarind, the vine, and other vegetables; and is deposited during the slow fermentation of wine in casks. It is purified by solution, filtration, and repeated crystallization: it has a sour taste; and requires for its solution 60 of cold, and 30 parts of boiling water. Exposed to heat it is decomposed; and its potash, united with a portion of carbonic acid, remains, forming the sub-carbonate of potash, which has been usually obtained from this decomposition.

The excess of tartarous acid in this salt is easily saturated by the addition of an alkali. If potash be added, the neutral tartarite of potash is obtained,—a salt which has a bitter taste, is deliquescent, and very soluble in water. If soda be used

ed to neutralise this excess, a triple salt is formed, known by the name of Rochelle salt, and employed in medicine as a pleasant laxative.

The acidulous tartarite of potash, from the excess of acid which it contains, is capable of dissolving a portion of several of the metallic oxyds. If boiled with oxyd of antimony, the excess of tartarous acid combines with the oxyd, and a triple compound of potash, ammonial oxyd, and tartarous acid, is obtained by crystallization.

The tartarous acid may be obtained from the acidulous tartarite by sulphuric acid; but the decomposition is not complete. A preferable process is to add to a solution of acidulous tartarite of potash in water, a quantity of lime sufficient to combine with the tartarous acid, and afterwards to decompose the tartarite of lime by sulphuric acid.

The solution of the tartarous acid, affords tabular crystals by evaporation, which are permanent in the air, and easily soluble in water. This acid, by exposure to a high temperature, affords carbonated hydrogen and carbonic acid, an acid

similar to the acetous, and an empyreumatic oil, charcoal remaining. It seems to differ from the acetous principally in containing less oxygen.

This acid combines with the alkalis and earths, its attractions being stronger to the latter than to the former. It has a strong tendency to combine with potash only in a limited quantity, so that the acid shall exist in the compound in excess; and hence potash is a test to discover this acid, this acidulous-salt, which is of sparing solubility in water, being formed.

BENZOIC ACID.

This acid exists in the balsams; in largest quantity, in the concrete balsam termed Benzoin, from which it may be extracted by the application of a very moderate heat. The acid is volatilised, and condenses in slender, white, brilliant crystals: or the benzoin powdered may be boiled with lime; a solution of benzoat of lime is obtained. If to this, when cold, muriatic acid is added, the benzoic is precipitated; and by solution in boiling water, it may be crystallized. This acid also exists in several

sal animal matters, especially in the urine of granivorous animals.

Acid of benzoïn has a slightly pungent taste and fragrant odour. It is sparingly soluble in cold, but abundantly in hot water; the latter solution crystallizes on cooling. It is soluble in alcohol; is volatilized by a moderate heat; and burns when strongly heated in contact with the air. It is soluble in sulphuric and nitric acids without decomposition. It combines with the alkalis and earths, its attractions being strongest to lime.

ACETOUS ACID.

This acid has been found combined with lime and potash, in the sap of the vine, and in a number of other vegetables. It is, however, more peculiarly the produce of fermentation, and will be more properly considered under the chemical history of that process.

GALLIC

GALLIC ACID.

This acid exists in all those vegetables termed Astringents. It is usually obtained from galls, either by macerating them in water, and allowing the infusion to stand exposed to the air for some months, during which small crystals adhere to the sides and bottom of the vessel, consisting of the gallic acid; or it may be obtained by exposing the powdered galls to a moderate heat, when the acid sublimes, and condenses, partly in small white crystals, and partly in a fluid form, from combination with a portion of water.

This acid has a sour taste; reddens the vegetable colours; is soluble in 24 parts of cold, and in 5 parts of boiling water. Exposed to heat, it is volatilised; and partially decomposed; and by a strong heat, quickly applied to it, its decomposition is complete; an empyreumatic oil, carbonated hydrogen and carbonic acid being produced. It is converted into oxalic acid by the action of the nitric acid.

The

The property by which this acid is peculiarly distinguished is that of producing a deep black colour with the salts of iron, when the metal in these is in a certain state of oxydation. This colour, for example, is produced by the red, but not by the pure green sulphat of iron. It appears, that part of the oxygen of the metallic oxyd is attracted by a portion of the hydrogen of the acid; that part of its carbon combines with the imperfect oxyd of iron; and that the union of this with the remaining gallic acid produces the black precipitate. This combination of iron with gallic acid is the basis of ink, and of black dyes.

This acid likewise precipitates the other metals from their solutions, of various colours. It unites with the alkalis and earths; and these salts still retain the property of changing the colour of the solutions of iron.

Besides these acids which exist in vegetables, there are some of an analogous nature, which are formed during certain decompositions of vegetable matter, —

matter,—such are, the Pyro-mucous, Pyro-ligneous, and Pyro-tartarous, the Suberic, and Succinic.

The three first of these which are obtained, — the first from the decomposition by heat of gummy or saccharine matter, the second from a similar decomposition of wood, and the third from that of acidulous tartarite of potash, — have been discovered to be the same acid, the acetic, disguised only by the mixture of empyreumatic oil.

The SUBERIC acid is obtained by distilling nitric acid from cork; the residuum is exposed to a moderate heat, till pungent suffocating vapours arise: to this twice its weight of water is added, and heat applied: and the solution of suberic acid thus obtained, is separated by filtration when cold. This acid may be obtained by evaporation, in a solid form: it is volatilised by heat; is soluble in water; has an acid bitterish taste; and combines with the alkalis and earths, and several of the metallic oxyds.

SECONIC acid is obtained by exposing the bituminous substance, amber, to a moderate heat; an empyreumatic oil, with an acid liquor, distil over, and

and a matter concretes in crystalline plates in the neck of the retort. This is the succinic acid. It may be purified by a second sublimation, or by solution in hot water, and crystallization. Its taste is acid; it is soluble in 24 parts of cold, and in 2 of boiling water, the latter solution crystallizing on cooling. Its crystals are permanent in the air, and are volatilised by heat. It combines with the alkalis and earths, and forms Succinats, distinguished by peculiar properties.

Sect. XIII.

TANIN.

THIS substance exists in the vegetable astringents, and was till lately confounded with the gallic acid, with which it is intimately mixed or combined: their properties, however, are different, and they can be obtained distinct.

When any vegetable astringent, oak bark for example, is macerated in hot water, the infusion contains the tanin and a portion of gallic acid. If a fresh quantity of water is added, the acid is obtained

obtained with scarcely any mixture of tanin; and by a third infusion, it may be procured in still greater purity. The tanin may also be separated from it by chemical means. If a solution of any animal glue be added to the watery infusion from a vegetable astringent, the glue, or gelatin, combines with the tanin, and forms a substance altogether insoluble. The gallic acid dissolved in water can therefore be obtained pure by filtration.

To obtain the tanin pure, a different process must be employed. To the infusion of the astringent substance, a solution of muriat of tin is added; an insoluble compound of tanin with oxyd of tin is formed: this, after being washed, is diffused in water, and a current of sulphurated hydrogen is passed through the liquor: this combines with the oxyd of tin, and the tanin is left dissolved.

This solution is of a brown colour; it has a bitter styptic taste. By evaporation, it may be obtained in a solid mass, which is still soluble in water. It combines with the acids, forming insoluble compounds.

Though

Though tanin has no acid property, it possesses the distinguishing quality of the gallic acid, — that of forming a dark-coloured precipitate with the red sulphat of iron. This precipitate is even more dense than that formed with the gallic acid: hence the colour which iron produces in the infusion of a vegetable astringent is deeper than that produced with the pure acid.

On the property which this principle has of combining with animal gelatin, is founded the art of tanning. When the skin of an animal, freed from the hair, is immersed in an infusion of oak bark, the tanin gradually combines with the gelatin of the skin; and the insoluble compound, being diffused through its substance, renders it dense and thick, and, when dried, less permeable to moisture. The gallic acid seems to facilitate the process, by slightly de-oxydating the skin, and bringing it more near to the state of gelatin.

Tanin may be applied to important medical purposes, as a test in discovering the morbid excess of gelatin in any of the secretions.

Sect. XIV. — COLOURING MATTER.

MODERN Chemists have generally supposed, that the colouring matter of vegetables resides in a particular proximate principle, different from any other. The justness of this opinion seems, however, to be doubtful, colour being a property belonging in general to some of their known principles. But there are some general facts on this subject which require to be noticed.

In different vegetables, this matter has different chemical properties. It is extracted from some by water; from others, by alcohol or oil. Its brightness may be heightened by various substances; and others are capable of attracting it from its solvents, of combining with it, and of serving as a medium of connection between it and other matter. On these principles are founded the arts of dyeing and of pigment-making.

The

The art of dyeing consists in fixing certain colours upon cloth or its materials. This is effected solely in consequence of the attraction of the matter to be dyed to the colouring matter. Hence, when plunged into a solution of this colouring matter, it attracts and fixes it, and of course acquires its colour. Wool and silk, which are of animal origin, attract colouring matter in general more strongly, and are of course dyed with more facility, than cotton or linen, which are vegetable productions.

In many cases, the substance to be dyed has too weak an attraction to the colouring matter to form a permanent dye. In such cases, a third substance must be used as the bond of union between them. Such substances are termed Mordants, of which argillaceous earth, certain metallic oxyds, especially those of tin, iron, copper, and arsenic, gallic acid, and tanin, are the principal. The cloth is immersed in solutions of these substances, so as to be impregnated with them, and is then immersed in the dye; or the mordant is sometimes mixed with the infusion of the colouring matter previous to the immersion of the cloth. Frequently mordants are used, not only to dispose
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the stuff to attract the colouring matter and fix it, but likewise to heighten the colour itself, or give it more brilliancy or durability.

The formation of vegetable pigments, or lakes, depends on the same principle. Some substance, capable of combining with the colouring matter, is added to its solution, and the compound, which is generally of very sparing solubility, is dried.

Sect. XV. — — LIGNEOUS FIBRE.

THIS is the base to which the other proximate principles are attached, the skeleton of the plant, and the principal part of many of its products. It is insipid and inodorous, and completely insoluble in water, or in alcohol. The alkalis do not act upon it. By the acids it is decomposed. Nitric acid converts it into oxalic and malic acids. Exposed to a high temperature, it affords empyreumatic, acetous, or pyro-ligneous acid, hydro-carbon, and carbonic acid, and leaves a large residuum of charcoal. It is from this decomposition of wood, that charcoal is obtained.

Sect.

Sect. XVI. — — AROMA, &c.

BESIDES the principles that have been enumerated as entering into the composition of vegetable matter, others have been stated of a more subtle kind, — as the Aroma, or Spiritus Rector, the Narcotic Principle, the Bitter Principle, &c.

Of these, the one whose existence as a distinct principle seems most probable, is the aroma, or principle on which the odour of vegetables depends. Although the flavour of plants generally resides in their essential oil, it has been observed, that several of the most odoriferous vegetables afford no essential oil; or if they do yield a small quantity, it is not very highly fragrant. At the same time these flowers diffuse their flavour thro' the air, lose it by a gentle heat, and communicate it to the water. It has, therefore been concluded, that they contain a principle more subtle and volatile than essential oil, on which their odour

odour depends; and that the fragrance of the essential oil depends on the presence of this principle.

There are, however, evident objections to this opinion. The faculty of exciting the sensation of odour, is a quality which may belong to any kind of matter, and which does belong to many substances, as ammonia, camphor, and several of the metals, in which we cannot suppose the existence of any aroma. It is a mere hypothesis to admit of its existence in any case; and the facts that have been stated in its support may be easily explained on the supposition that the distinguishing odour of vegetables is resident in some of their proximate principles, generally in their essential oil; and that this is more or less volatile, is capable of combining with atmospheric air, or is soluble in water or other fluids.

The existence of other principles of this kind is still more doubtful; bitterness, the narcotic quality, and others, not being dependent on distinct principles, but on peculiarities of composition in the known parts.

CHAP. III.

OF THE CHANGES WHICH VEGETABLE MATTER SUFFERS.

Sect. I. — FERMENTATION & its PRODUCTS.

WHEN vegetable matter is placed in a certain temperature and degree of humidity, its principles begin to re-act on each other ; they spontaneously enter into new combinations, and form peculiar products. It is this process which is termed Fermentation, of which three kinds are noticed, the vinous, acetous, and putrefactive, characterised principally from the nature of their products.

VINOUS

VINOUS FERMENTATION.

It has been proved that saccharine matter only is susceptible of the vinous fermentation. Fecula likewise undergoes it, but only by previously passing into the state of sugar. This constitutes the process of malting, in which, by the due application of heat and moisture, germination is excited in the grain, oxygen is absorbed, and carbonic acid evolved, and the fecula of the grain is converted into sugar.

When saccharine matter dissolved in water, or when any sweet vegetable juice, is exposed to a temperature between 60° and 80° of Fahrenheit, it becomes more or less turbid, and bubbles of air are disengaged; the sweetness disappears, and a pungent taste is acquired. After a certain time, this change is completed; the disengagement of air ceases, and the fluid, depositing a sediment, becomes transparent. The change of properties is found to be owing to the conversion of the saccharine matter into a new compound, pungent, odorous, volatile, and inflammable, — which can be separated from the liquor by distillation :

lation: it is the Alcohol of the modern nomenclature. The general process is much facilitated by the previous addition to the liquor of a ferment; that is, of a portion of the matter deposited from a liquor which has already fermented.

Lavoisier, ascertained by experiment the theory of this process. He found that it can be carried on without the access of atmospheric air, that the water of the fermenting fluid is not decomposed, and that the saccharine matter only is changed. This matter consists of carbon and hydrogen, with a large proportion of oxygen. During the fermentation, a large quantity of carbonic acid is formed and disengaged. The whole process, therefore, is nothing but new combinations of the principles of the sugar; the greater part of its oxygen and carbon combine, and form carbonic acid, and its hydrogen combines with its remaining carbon and hydrogen, forming the alcohol, which is the only other product of the fermentation.

By this process, the different fermented liquors, those from the juice of the grape and of other
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fruits, and from the different kinds of grain are formed. The latter require previously to be subjected to the process of malting, to convert their fecula into sugar. These liquors vary in their qualities according to the matter from which they have been prepared, the perfection of the fermentation, and the manner in which it has been conducted ; but they agree in certain properties, — in a greater or less degree of pungency, and in their stimulating and intoxicating effect on the animal system.

From these fermented liquors, a fluid is obtained by distillation, highly pungent and stimulating, volatile, and inflammable. This is termed Ardent Spirit, and differs in its flavour and some other qualities, according to the kind of fermented liquor from which it has been obtained. These spirits consist of alkohol, more or less diluted with water, and mixed with some oily matter, which gives them their peculiar taste and flavour.

To obtain alkohol from any of these spiritous fluids, it may be subjected to repeated distillations, by which the water and oily matter are abstracted. This may be facilitated, however, by
certain

certain additions. After the spirit has been once distilled, the product is mixed with dried carbonate of potash, and subjected to another distillation by the heat of a water bath. The spirit thus obtained is nearly free from water. To remove from it a disagreeable odour, which it acquires from the alkali, one-twentieth of its weight of powdered alum is added, and it is again distilled from the water bath. It still contains a minute portion of water, from which it can only be freed by repeated distillation.

The fluid thus obtained is pure alcohol. Its strength and purity are most accurately estimated by its specific gravity. Common alcohol has a specific gravity to that of water as 815 to 1000 : by very careful rectification with a large quantity of potash, it has been brought to the specific gravity of 791. The specific gravity is usually determined by means of the hydrometer. Other means have been used to ascertain the strength of alcohol ; as, the firing of gunpowder by its burning, or the quantity of water left after its combustion : but these are liable to numerous and important sources of error.

Pure

Pure alcohol is colourless and transparent; its odour is fragrant; its taste pungent. It is very volatile, it evaporates at the medium temperature, and boils under the atmospheric pressure at 165° . It is also highly inflammable, though no great quantity of caloric is extricated during its combustion. The products are water and carbonic acid; 18 ounces of water being obtained from the burning of 16 ounces of alcohol. By passing it through an ignited earthen tube, it is converted into water, carbonic acid, carbonated hydrogen, and a small portion of carbon.

From the products of its combustion, Lavoisier endeavoured to estimate the proportions of its principles; and he concluded that 100 parts of it are composed of 28.5 of carbon, 7.8 of hydrogen, and 63.5 of water. This water he supposed to be essential to its composition: but his experiments do not warrant this conclusion; nor is it certain but that it may rather contain the elements of this water than the water itself; and that, of course, instead of being a compound of carbon and hydrogen combined with water, it may be a triple compound of carbon, hydrogen, and oxygen.

Alcohol

Alcohol combines with water in every proportion. The specific gravity of the combination of the two is never the mean of the specific gravities of the respective fluids, but is always greater. This combination is accompanied with a diminution in the capacity for caloric; and hence a rise of temperature always accompanies it. The combination of alcohol with an equal weight of water forms Proof spirit.

Alcohol dissolves the alkalis and many of the neutral salts, especially those which have ammonia, lime, or magnesia for their base, and which contain nitric or muriatic acid. Other salts it precipitates from water, by exerting a stronger attraction to that fluid.

Alcohol unites with sulphur, when the two are presented to each other in the state of vapour. It dissolves phosphorus sparingly: this solution is decomposed by water.

Alcohol is a solvent of several of the vegetable proximate principles, as essential oil, camphor, resin, &c.: hence it is able to extract the active matter of many vegetables. When diluted with an
equal

equal part of water so as to form proof spirit, its solvent power is still more extensive. Both the pure and diluted spirit are much used in pharmacy to dissolve the principles on which the virtues of many remedies depend. Such solutions are termed Tinctures, or Elixirs.

The action of acids upon alcohol is peculiar and important. The alcohol is decomposed, and a new compound is formed. This differs somewhat in its properties, according to the acid used in its preparation. The different kinds, however, agree in the possession of certain properties: they are highly volatile, odorous, pungent, and inflammable, miscible with water, and capable of combining with alcohol. They are termed Ethers.

To prepare Sulphuric Ether, any quantity of sulphuric acid is poured upon an equal weight of alcohol in a retort; and after they are mixed by gradual agitation, heat is applied by a sand bath, the retort being connected with a range of receivers kept cool by water. The liquor boils at the temperature of 208° , and a colourless fluid condenses in the receivers. When the distilled liquor amounts to about half the quantity of alcohol employed

ployed, or when the neck of the retort becomes obscured with white fumes, the distillation is to be stopped; a thick black fluid remaining in the retort. The distilled liquor, which is the ether impure, from the admixture of water and sulphureous acid, is to be mixed with a small quantity of potash, or with black oxyd of manganese, and subjected to distillation by a very gentle heat. It is thus obtained nearly perfectly pure.

The theory of the formation of ether is far from being accurately ascertained. According to the explanation which, till lately, was generally received, in the formation of sulphuric ether, the alkohol is decomposed by part of its hydrogen attracting part of the oxygen of the sulphuric acid: the balance of attractions existing between the principles of the alkohol being thus broken, a large quantity of carbon is precipitated, and the remaining elements of the alkohol combine, and form the ether.

But it has been affirmed by Fourcroy and Vauquelin, that, during the formation of ether, none of the sulphuric acid is decomposed. They suppose, therefore, that the acid promotes the decomposition

position of the alcohol, merely by a disposing affinity ; it causes part of the hydrogen and oxygen of the alcohol to combine, and form water—a large portion of carbon is precipitated, and the ether is formed from the combination of the remaining quantities of the constituent principles of the alcohol.

This latter explanation is perhaps scarcely sufficiently established. The facts which these chemists state, as proving that the sulphuric acid is not decomposed, are, that no sulphureous acid gas is produced ; and that the liquor remaining after the process is able to saturate as much of an alkali as the quantity of acid employed could do in its pure state. Sulphureous acid may, however, be produced in small quantity, and not be apparent from combining with the alcohol or the ether :—and with regard to the experiment respecting the quantity of alkali saturated by the liquor, it is one not only extremely difficult to make with perfect accuracy, but is liable to a fallacy which invalidates the conclusion. During the formation of ether, oxalic and acetous acids are always formed ; and these existing in the residual liquor, must contribute to the saturation of the alkali. A fact which

which appears to prove, that the acid contributes to the formation of ether in some other way than by a disposing affinity, is, that ether cannot be formed from those acids which do not part with oxygen easily, — from the muriatic, for example ; while from those which do so, as the nitric or oxygenated muriatic, it is formed with facility.

Whatever opinion, however, may be formed as to the mode in which the changes that occur in the process of making ether are effected, the nature of the changes themselves seems sufficiently ascertained. It is proved, that part of the hydrogen of the alkohol is spent in the formation of water ; a still larger portion of carbon is deposited ; the remaining elements therefore combine to form the ether. This compound seems to differ from alkohol principally in containing a larger proportion of hydrogen, to which its greater levity and volatility may be owing. It has accordingly been affirmed, that more water, and less carbonic acid, are produced from its combustion, than from the combustion of alkohol.

Towards the end of the process by which sulphuric ether is formed, an oily matter distils over,

termed Sweet Oil of Wine, which some have considered as a compound of ether and sulphureous acid; and others, as a compound analogous to ether, and differing from it in containing a larger proportion of carbon. There is also discharged, in this stage of the process, a gas of a peculiar kind, a compound of carbon and hydrogen; and if the application of the heat be continued, sulphureous acid gas is suddenly disengaged, the liquor swells, and is apt to boil over into the receiver.

With other acids, alcohol forms ethers differing in some respects from sulphuric ether.

The preparation of Nitric ether is extremely difficult on account of the violent action of the acid on the alcohol, when they are mixed together in the due proportion. It may be formed by adding cautiously, and in small quantities at a time, nitric acid to an equal weight of alcohol, in a retort connected with the bottles of Woolfe's apparatus: the nitric ether partly distils over, and partly remains in the retort on the surface of the remaining acid liquor. It may be poured off, and rectified by distillation with a very gentle heat.

For

For medicinal use, the process usually employed to obtain this ether is, to add one part of nitric acid to three of alcohol; allow them to digest and distil with a gentle heat; the product, the *Dulcified Spirit of Nitre*, as it is termed, is nitric ether, combined with a quantity of alcohol, and generally with a portion of uncombined acid, from which it may be freed by a second distillation, with the addition of a small quantity of alkali.

The theory of the formation of nitric ether is not less obscure than that of the production of sulphuric ether. It has been ascertained by the experiments of Bayen, that the acid is either decomposed, or combined in such a manner that it is not discoverable by an alkali; as the mixture of the acid and alcohol, after being digested for some time, he found, required only the ninth part of the quantity of potash for its saturation, which the quantity of acid employed would have done. The alcohol is also partially decomposed, as oxalic and acetic acids are formed. No carbon, however, is precipitated in a sensible form. It may be said, perhaps, that in this process, part of the carbon, hydrogen, and oxygen of the alcohol enter into new combinations, forming the acetic and

and oxalic acids; and that the remaining quantities of these elements combine with part of the acid to form the nitric ether.

Muriatic acid does not act upon alcohol: but the oxygenated muriatic acid forms with it an ether. The mode of preparing it, is to expose to heat, in a retort, two parts of dried muriat of soda with one part of black oxyd of manganese; three parts of alcohol, and one of sulphuric acid.—Acetic and phosphoric ethers can likewise be obtained by distilling the acids with alcohol, with the addition of oxyd of manganese, to furnish oxygen.

These ethers possess nearly the same properties, being extremely light, volatile, fragrant, and inflammable. Sulphuric ether, when completely rectified, has a specific gravity equal only to 7.16. It evaporates at the common temperature of the atmosphere; it boils *in vacuo* under the common atmospheric pressure. Nitric ether, it has been alleged, is still more light and volatile.—These and the other ethers are soluble in water in certain proportions, and entirely soluble in alcohol; they act

as

as solvents on many of the vegetable proximate principles.

When alcohol or ether is passed through an ignited earthen tube, or an ignited glass tube containing siliceous or argillaceous earth, a peculiar gas is obtained. It is also disengaged when three parts of fulphuric acid are poured upon one of alcohol, and a moderate heat is applied. This gas is very little lighter than atmospheric air, the specific gravity of the one being to that of the other as 995 to 1000. Its smell is fœtid: it is not absorbed by water: kindled in atmospheric air, it burns with a dense oily-like flame, affording carbonic acid and water. When an equal part of oxygenated muriatic acid gas is added to it, a mutual decomposition takes place, there is a diminution of volume, and a matter is deposited having the properties of an expressed oil. From this remarkable property, this gas has been named the Olefiant Inflammable Gas. When passed through an ignited porcelain tube, carbonic acid and hydrogen gases are disengaged, carbon being deposited. It is therefore a triple compound of carbon, hydrogen, and oxygen, the proportion of carbon being large.

If

If alkohol or ether be passed through an ignited glass tube, gases somewhat different from the former, and even from each other, are obtained. They are not so heavy as the olefiant gas, and are not acted on in a similar manner by oxygenated muriatic acid. They probably contain less carbon. The gas thus obtained from sulphuric ether has a specific gravity to atmospheric air as 709; that from alkohol, 456.

When equal parts of nitric acid and alkohol are mixed together, and heat is applied, a gas is disengaged, which is slowly absorbed by water, explodes when mixed with oxygen and kindled, and is decomposed by sulphuric, nitric, and muriatic acids, which disengage from it nitrous gas. It is termed Nitrous Etherial Gas, and is probably a combination of nitrous gas and nitric ether.

ACETOUS FERMENTATION,

After the vinous fermentation is completed, if the liquor be exposed to a temperature between 75° and 85° of Fahrenheit, it loses its fragrance and pungency, and becomes sour. This change is termed

termed the Acetous Fermentation: the product is Vinegar, or Acetous acid.

The excess of the atmospheric air is necessary to this species of fermentation: its oxygen is absorbed, and little or no carbonic acid is evolved. The process, therefore, seems to be little more than the oxygenation of the alcohol; and it is found, that the strength of the vinegar is proportioned to the quantity of alcohol, or of matter capable of being converted into alcohol, that the liquor contained.

Though fermented liquors and saccharine matter are best fitted to undergo the acetous fermentation, yet other substances suffer a similar change, such as fecula, mucilage, animal gelatin, and milk. The sourness, however, which some of these acquire, is not owing to the formation of acetous acid; and perhaps no principle is susceptible of the acetous fermentation, but saccharine matter, or fecula, which is convertible into sugar.

Vinegar, fully fermented, is clear and nearly limpid; has a pleasant pungent smell, and a sour taste; it possesses all the properties of an acid.—

This

This acid is termed the Acetous. In vinegar it is diluted with water, and mixed with mucilaginous and extractive matter, and frequently with acidulous tartarite of potash. It is usually freed from those substances by distillation, the acid and the water passing over. Distilled vinegar, however, is very weak, and has always more or less of an empyreumatic odour, from the burning of the mucilaginous matter by the heat applied. Concentrated acetous acid is obtained by saturating the distilled vinegar with potash or soda, and decomposing the salt, by adding to it half its weight of sulphuric acid. The acetous acid is separated, and may be obtained by distillation.

When the vinegar is saturated with a metallic oxyd, the acid obtained by decomposition of the compound by heat, is different in its properties from the concentrated acetous acid. It is much more pungent, caustic and volatile; has a stronger attraction to water, and exerts a stronger action on the metals, oxydating and dissolving them. These differences, it has been proved, are owing to the latter acid containing less carbon; the metallic oxyd of the salt from which it is obtained attracting part of its carbon. It is usually procured

red by distillation in close vessels from acetite of copper, or verdegriſ; and, to diſtinguiſh it from the acetous acid, is named Acetic Acid, or Radical Vinegar. Both are ternary compounds of carbon, hydrogen, and oxygen, containing more oxygen than the greater number of the vegetable acids.

The combinations of the acetic acid with the alkalis, earths, and metals, have ſcarcely been examined; thoſe with the acetous are better known. The ACETITE of POTASH, obtained by ſaturating potaſh with diſtilled vinegar, is in the form of a white foliated maſs, extremely deliqueſcent, ſoluble in little more than its weight of water at the temperature of 60°, and likewiſe ſoluble in alcohol. The ACETITE of SODA can be obtained in ſlender prismatic cryſtals, which, inſtead of effloreſcing, deliqueſce on expoſure to the air.—The ACETITE of AMMONIA can ſcarcely be cryſtallized, as it is partly volatilized with the water when its ſolution is evaporated, and is partly decompoſed.

Of the earthy acetites, the only one applied to uſe is that of argil. It is prepared by mixing

solutions of acetite of lead and fulphat of argil together. The liquor thus obtained is used as a mordant in dyeing and cloth-printing.

Of the metallic acetites, it is necessary to notice those only of copper, lead, and mercury.—The *ACETITE of COPPER* is used as a pigment, under the name of Verdigris. It is prepared by stratifying copper plates with the husks and stalks of grapes in a state of fermentation, and moistening them with sour wine or vinegar: a green crust is formed, which is oxyd. of copper partly combined with acetous acid. It is completely saturated with the acid by dissolving it in distilled vinegar; the solution affording, by evaporation, regular crystals, of a rich green colour. The *ACETITE of LEAD* is prepared by digesting cerusse, or white oxyd of lead, with vinegar: a salt is obtained, by evaporation, in small needle-like crystals, known in commerce by the name of Sugar of Lead.—The *ACETITE of MERCURY* is obtained by adding a solution of acetite of potash to a solution of nitrat of mercury: it crystallizes in slender brilliant scales. It has been employed in medicine as a mild preparation of this metal.

From

From acetic acid, an ether is formed by digesting equal parts of the acid with alcohol, and distilling the mixture. The product is fragrant, and highly volatile and inflammable.

A species of fermentation, analogous to the vinous or acetous, is that which takes place in the making of Bread. A small quantity of yeast is mixed with the flour of which the bread is to be baked : a degree of fermentation is excited ; and the mass is rendered light and porous from the disengagement of numerous air bubbles. It very speedily runs into the acetous fermentation, but is checked by immediately baking the bread : it is the cause of its sponginess, porosity, and consequent lightness.

PUTREFACTIVE FERMENTATION.

This term is applied to that process by which vegetable matter is ultimately resolved into products which escape in the gaseous form, and leave only the portion of saline and earthy matter which the vegetable contained. Thus, if any vegetable matter, dissolved or suspended in water,

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be exposed to the air for some time, its surface becomes covered with a mould; carbonic acid is extricated, probably with carbonated hydrogen; and at length little remains but the mould, which is likewise gradually decomposed in a similar manner. In many vegetable substances, this decomposition is accompanied with an evolution of ammonia: they are then more peculiarly said to putrefy, as the process is analogous to the putrefaction of animal matter.

*SECT. II.**OF BITUMENS.*

AMONG the decompositions which vegetable matter suffers, may probably be ranked that by which bitumens are formed. These are inflammable substances, generally of a strong smell, fluid, soft, or solid, and affording, by distillation, an empyreumatic oil. They are found exuding from crevices, floating on waters, or forming strata in the earth. They consist of the same principles as vegetable matter, of carbon, hydrogen, and oxygen; and there are often mixed with them remains of vegetable matter. It is, therefore, sufficiently

Sciently probable, as has been supposed, that they originate from the slow decomposition which vegetable substances suffer when buried in the earth, modified, perhaps, in some cases, by the action of heat, without the access of air. The principal substances of this kind are Naptha, Petroleum, Asphaltum, Amber, Coal, and Melilite.

NAPTHA is a white or yellowish fluid, of a penetrating smell, volatile, and highly inflammable; having a specific gravity from 708 to 847. It is insoluble in alkohol. It dissolves oils, resins, and elastic gum. PETROLEUM is a similar substance, but of a thick consistence, brown or black colour, less agreeable odour, less volatility, and inflammable. By distillation it affords a fluid similar to naptha. ASPHALTUM seems to be the same kind of matter, altered by exposure to the air: it is solid and brittle; of a brown or black colour; is without transparency, but with a lustre equal to 2. or 3.: its fracture is conchoidal. It melts by heat, and, when air is admitted, inflames. Decomposed by heat, it affords an empyreumatic oil, carbonated hydrogen, and carbonic acid. These three varieties agree in leaving no earthy residuum when burnt.

COAL

COAL differs from the preceding substances in containing earthy and carbonaceous matter, the different proportions of which give rise to its different varieties. It burns with flame and smoke, and leaves a residuum of ashes. Exposed to heat in close vessels, it affords an empyreumatic oil, carbonated hydrogen, carbonic acid, ammonia, and sometimes sulphureous acid. The residuum is carbonaceous matter; and when burnt to whiteness, its ashes are chiefly argillaceous earth, with oxyd of iron. Coal is found in extensive strata, and often contains the remains of, or impressions of organic substances,

JET is a substance of a nature intermediate between coal and asphaltum. Its colour is pure black; transparency 0.; lustre from 3. to 4.; hardness 6. or 7.; fracture striated. It burns with a greenish flame, and leaves little ashes.

AMBER is a bituminous concrete, of a yellow colour, and more or less transparency; lustre 3.2.; hardness 5.6.; fracture conchoidal. It softens and melts by heat, and burns with a greyish flame, leaving a coaly residuum. When it is exposed to heat in close vessels, carbonic acid and
carbonated

carbonated hydrogen are difengaged, with an empyreumatic oil: a salt likewise sublimes, the fucinic acid, which has been already noticed.

MELILITE, or Honey-stone, is a peculiar substance, which may be ranked with the bitumens. It has a light yellow colour, from which its name has been derived; is generally crystallized; transparency 4.; lustre 2.3. It is found in strata of bituminous wood. When exposed to heat, it becomes white, and burns, but without flame, unless at a white heat. It is not soluble in alcohol or oils. It consists of argil, with a peculiar acid, very analogous to the oxalic.

ANIMAL

ANIMAL SUBSTANCES.

CHAP. I.

FORMATION OF ANIMAL SUBSTANCES.

ANIMAL, like vegetable substances, are formed from a few simple principles ; the differences in their properties arising from differences in the proportions and modes in which these are united. They are liable to decomposition from slight causes from their principles reacting on each other, and entering into new combinations.

Animal substances are more liable than vegetable matter to that species of spontaneous decomposition termed Putrefaction : and when exposed to heat, besides the usual products which vegetables yield by the same operation, they invariably furnish a large quantity of ammonia, and generally

herally foetid gases, consisting of hydrogen, azot, sulphur, and phosphorus: the solid residuum contains iron and phosphoric salts.

The differences between the animal and vegetable products arise from differences in their composition. The former, along with carbon, hydrogen, and oxygen, always contain azot, generally phosphorus, and not unfrequently sulphur. The presence of these principles, particularly of the azot and phosphorus, by dividing the attractions subsisting between the carbon, hydrogen, and oxygen, weaken their force; and hence the susceptibility of decomposition which characterises these products. The new combinations of these principles produce the ammonia, the prussic acid, and the other substances which their decomposition affords.

Another general difference in composition between animal and vegetable substances is, that the former contain less carbon and more hydrogen than the latter. Carbon appears to be the base of vegetable matter to which oxygen and hydrogen are attached. Hydrogen is, perhaps, the princi-

pal component part of animal matter, combined with azot, carbon, oxygen, and phosphorus. In general, the animal substances contain less oxygen than the vegetable; and hence they afford less acid when decomposed.

As all animals live directly or indirectly upon vegetables, the animal products must be derived from changes effected on vegetable matter. These changes are effected in the animal system by the functions of Digestion, Respiration, and Secretion.

In the process of Digestion, the food, after being masticated, is exposed in the stomach to a temperature considerably superior to that of the surrounding atmosphere; it is mixed with the gastric juice; and in many animals is subjected to pressure or trituration, from the forcible contractions of the stomach. It is thus converted into a soft mass of a greyish colour, in which the texture or nature of the food cannot be distinguished. In the production of these changes, the gastric juice, by its solvent power, appears to be the principal agent, assisted, no doubt, by the heat and moisture, and in granivorous animals by the contraction of

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of the stomach. The alimentary matter does not seem to be resolved into its ultimate elements, so as these might be again brought into new combinations. The soluble parts are rather only separated from the insoluble, are brought into a state of intimate mixture with each other, and are partially animalised by the addition of the saliva and gastric juice, by which probably its further assimilation is facilitated.

The Chyme, as this pulpy mass is termed, passes into the intestinal canal, where it is mixed with the pancreatic juice and bile ; and is still exposed to the same temperature and alternating pressure. The thinner parts of it are absorbed by the slender tubes terminating on the internal surface of the intestines, termed the Lacteals. It then forms the chyle, a fluid of a white colour, and mild to the taste. This passing through the glands of the mesentery, is conveyed by the thoracic duct into the blood.

We know little of the nature of the series of changes which constitute chylication. In the intestines, it is probable, that the already partially assimilated aliment is combined with some of the principles

principles of the bile, and of the other intestinal fluids. In passing through the mesenteric glands, it probably suffers further changes, of the precise nature of which, however, we are ignorant: but by the general process it is evident, that it is assimilated to the nature of animal matter, as it possesses the property of albumen, of being coagulated by heat.

The chyle mixed with the lymph conveyed by the absorbents, quickly disappears, after being received into the blood. The blood, passing to the heart, is conveyed to the lungs, where it circulates over a very extensive surface presented to the atmospheric air, with the intervention of a very thin membrane, which does not prevent their mutual action. The blood loses a quantity of carbon, which is attracted from it by the oxygen of the air; part of it being probably derived from the imperfectly assimilated chyle. At the same time a portion of oxygen, and, as late experiments appear to prove, another of azot, are absorbed.

The process of sanguification is probably still not completed. The blood, during its circulation in the extreme vessels, is converted from the arterial

rial

rial to the venous state ; and though this is connected with the different species of secretion, yet it is probable also, that in these vessels the process of animalisation is completed. There remains as the result of it a redundance of carbon ; and the venous blood is again brought back to the heart, and conveyed to the lungs, where this excess of carbon is discharged.

The blood thus formed is a heterogeneous mass, composed of several proximate principles. The solids of the body seem chiefly to derive their nourishment from it by directly attracting these principles. There is another process, however, that of secretion, by which new products are likewise formed ; the blood being conveyed, in the course of the circulation, to organs termed Glands, in which its composition is entirely changed.

This process is evidently chemical, as the products of it are totally different from any pre-existing in the mass of blood. If we enquire into the nature of the chemical actions that are exerted, or of the powers by which new combinations are effected, we find the subject involved in the utmost obscurity. In the structure of the glands, we perceive

ceive nothing but a series of minute convoluted vessels, through which the blood circulates; and we are unable to discover how the action of these vessels operates in the formation of new products.

Some physiologists have cut short this difficulty, by saying, that secretion is the effect of the *vital power* of the secreting organ,—not aware, perhaps, that this is only substituting a term for an explanation, that it is merely acknowledging an occult cause. Digestion was for a time ascribed by those who were dissatisfied with the hypotheses of fermentation or of mechanical trituration, to *vital action*; and the production of animal heat was referred to the same cause. We now know, that these are the effects of processes strictly chemical; and we have every reason to regard secretion in a similar point of view.

It might be supposed, as one mode of solving these difficulties on chemical principles, that the matter of which the gland itself consists exerts an attraction to one or other of the principles of the blood, by which the order of attractions being broken, new products may be formed. But the obvious objection to this opinion is, that the glandular

dular matter must undergo a proportional change, —a change utterly incompatible with the office it is designed to perform, or even with its existence as an organised part.

Perhaps the cause productive of the new combinations arising from secretion is the simple approximation of the elements of the blood, by its circulation through the very minute vessels which constitute the glands. In compounds consisting of several principles, the attractions existing between them are no doubt modified by the distances at which they are placed; and if their relative situations be altered by any mechanical cause, or by the expansive power of caloric, the existing attractions will be changed, and new combinations will take place. The blood in its circulation is propelled, by a *vis a tergo*, through canals of extreme minuteness; its particles are thus approximated, and may of course unite in different modes. It is perhaps impossible to point out the precise combinations which must arise from such a cause; but it is conceivable, that from its operation new products may be formed, and that the blood, by passing through vessels of different diameters, alternately contracting and enlarging, may

undergo

undergo many successive decompositions, and afford all the variety of products which arise from secretion. The formation of these may be still further diversified by the structure of the secreting organ, by which part of the blood partially changed, or even part of the new products that have been formed, may be withdrawn, and returned into the circulating mass.

From secretion, a variety of products are formed,—as bile, milk, urine, fat, the matter of bone, and others. These complete the formation of animal matter, and comprehend its several varieties.

Since the different kinds of animal matter are ultimately formed by the processes of digestion and respiration, it becomes an object of inquiry, whether from the principles known to be conveyed by these processes, the formation of these products can be explained.

With respect to carbon, hydrogen, and oxygen, which constitute so large a proportion of animal matter, it is evident there can be no difficulty.

ty, as they exist in abundance in vegetable matter, and of course are contained in the food.

To explain the origin of azot seems more difficult, as it is contained only in inconsiderable proportion in vegetable matter. An obvious source whence it might be received into the system is respiration. Dr. Priestley, in investigating the changes produced on the air by that process, supposed that part of the azot was absorbed; and an inconsiderable absorption of it seemed likewise to be proved by the experiments of Dr. Goodwyn. Those of Lavoisier and Laplace appear to establish the opposite fact, that the azot of the atmosphere remains unchanged by respiration. Mr. Davy, however, has lately found the consumption of this principle to be considerable, not less than 5.2 cubic inches in the minute: and if his experiments be confirmed, a source is pointed out whence all the azot contained in the animal system may be derived. It is likewise possible, that azot may be a compound substance, formed by some combination of carbon, hydrogen, or oxygen; or that, if simple, it may be a component principle of one or other of these substances: and

either of these suppositions will account for its existence in the animal products.

Phosphorus is another substance existing in much less quantity in vegetable than in animal matter. Its origin is equally obscure. It has been supposed to be a product of the process of animalisation ; which appears not improbable, from the large quantity of phosphoric acid in almost all the animal products. A considerable proportion of it, however, is also contained in those proximate principles of vegetables which are chiefly subservient to animal nourishment.

With respect to lime and iron, the two principal remaining substances which enter into the composition of animal matter ; as they are contained, in greater or less quantity, in almost every kind of vegetable matter, their origin in animal substances seems less ambiguous. The facts that have been stated as unfavourable to the opinion that they are conveyed by the food, are either inconclusive or founded on very vague and inaccurate experiments.

CHAP. II.

OF THE ANIMAL PRODUCTS.

Sect. I. — — — BLOOD.

THE Blood is the fluid whence all the animal products are formed. It varies in its qualities in the different tribes of animals : in insects, and in some others, it is pellucid, or white ; in the more perfect animals it is red, becomes florid on exposure to atmospheric air or oxygen, and is darkened by the noxious gases. Its consistence is thickish, its taste sweetish and fatuous, and it has a perceptible odour.

Though blood circulating in the body appears to be a homogeneous fluid, the microscope discovers it to be a heterogeneous mixture of particles apparently globular, swimming in a fluid. On
being

being taken from the body, and allowed to remain at rest for some time, it separates into a fluid, of a yellowish colour and slight tenacity, and into a coagulum, more or less firm, of a dark red colour. This is termed the Coagulation of the Blood: the fluid part is the Serum; the solid, the Clot, or Crassamentum. The latter is a mixture of two substances,—of the colouring matter, which can be carried off by water, and of a solid white elastic matter termed the Gluten, Coagulable Lymph, or Fibrin.

The cause of the coagulation of the blood has not been ascertained. It takes place more readily when the blood is at rest, and when the temperature is below 96°. The access of atmospheric air is not necessary, as it takes place *in vacuo*; and it has been affirmed, that it coagulates with nearly equal celerity when exposed to different gases.

Blood is likewise coagulated by heat, and by the addition of acids or alcohol; but this coagulation is different from that which takes place spontaneously. Alkalis render it more fluid.

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The spontaneous separation of the blood into serum, colouring matter, and fibrin, leads to their distinct examination, to ascertain its constituent principles.

Serum is a fluid slightly viscid, of a yellowish colour, and an insipid, somewhat saline taste, about one-tenth heavier than water. It is miscible with water in every proportion. Exposed to a moderate heat, about 165° of Fahrenheit, it coagulates. It is also coagulated by alcohol, acids, acidulous salts, and by several metallic oxyds. The substance thus separated is termed Albumen. It is one of the most abundant principles of animal matter.

Albumen is soluble in water; and if not more than 8 or 10 parts of water be used, is coagulated by heat. It is also coagulated by those substances that coagulate the serum. After coagulation, it is no longer soluble in water. It is dissolved by the alkalis, by ammonia very slowly, by potash and soda more rapidly. During its solution by the fixed alkalis, a quantity of ammonia is disengaged. Acids also dissolve albumen. By the nitric acid it is decomposed; nitrous gas is disengaged, and

and an oily-like substance, soluble in alcohol, is precipitated.

Albumen, when decomposed by heat, affords the usual products of animal matter. It appears to contain sulphur; as, by digesting a solution of silver with it, sulphuret of silver is obtained. Its residuum contains phosphates and carbonates of soda and lime, and muriat of soda.

If the coagulum obtained by having exposed serum to heat, be cut and pressed, a liquor somewhat turbid is obtained: it mixes easily with water. When this is made to boil, on cooling it concretes, or becomes gelatinous. By this experiment we discover the existence of another principle in serum, which is soluble in water, and which does not separate from it on being heated, but forms with it a perfect solution of a gelatinous consistence. This principle is termed Gelatin, and it forms a principal part of many of the animal solids.

This principle may be detected in the serum by chemical tests, particularly by a solution of tanin, which combines with the gelatin, and forms an insoluble compound. Alcohol,
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and the mineral acids, precipitate it. Nitric acid heated upon it decomposes it; a large quantity of gas is discharged, and oxalic acid is formed. Exposed to heat, gelatin affords carbonic acid, carbonated hydrogen, carbonat of ammonia, and an empyreumatic oil, the residuum being charcoal, containing phosphat of lime.

The liquor remaining after the separation of the albumen and gelatin from the serum is little else than a solution of certain saline substances, of which the principal are pure soda and muria of soda, with some salt containing phosphoric acid. From the presence of the soda, it has the property of changing the more delicate vegetable colours to a green.

Serum is thus to be considered as a solution of albumen and gelatin, with certain saline matters, in water.

The other substance obtained by the spontaneous coagulation of the blood, the Crassamentum, is of a dark red colour, which, by exposure to atmospheric air or oxygen gas, becomes more florid, while it is darkened by hydrogen, azot, and carbonic

bonic acid. It does not putrefy quickly by exposure to the air, and by exposure to a moderate warmth it may be dried. Exposed to a strong heat it is decomposed, affording the usual products of animal matter. The remaining charcoal contains a considerable quantity of oxyd of iron, and several salts, having lime and the fixed alkalis for their bases, and phosphoric acid principally for their other constituent principle.

The Crassamentum is not a homogeneous substance, but a mixture of two principles which can be very easily separated. If water be poured on it, the fluid acquires a red colour; and by repeated washing, a white fibrous matter remains. By this simple analysis, therefore, the crassamentum is resolved into two principles,—a colouring matter, soluble in water, and a solid insoluble substance. The former is termed the Colouring Matter of the Blood, or the Red Globules; the latter, the Gluten, Coagulable Lymph, or now more generally Fibrin.

The colouring matter has been supposed, from microscopical observations, to be spherical particles. It is soluble in water, but suffers a gradual

al decomposition, a matter being deposited from the solution. It is acted on by the gases, its colour being changed. When decomposed by heat, it affords carbonated hydrogen, sulphurated hydrogen, prussiat of ammonia, and empyreumatic oil; the remaining charcoal containing carbonat, phosphat, and muriat of soda, with carbonat and phosphat of lime, and oxyd of iron.

The Fibrin, which forms the basis of the crassamentum, is a ~~solid~~ white substance, inodorous and insipid, of a fibrous texture, and elastic. It is insoluble in water, except by long boiling. The alkalis dissolve and decompose it; potash or soda disengage from it ammonia, and precipitate a carbonaceous matter. The acids likewise dissolve it, but at the same time alter it, as the matter precipitated from these solutions by an alkali has not the properties of fibrin. Nitric acid diluted disengages from it a very large quantity of azot, which Berthollet proved was extricated from the fibrin, and not from the acid. Oxalic acid, with small portions of malic and acetic acids, are formed. Decomposed by heat, fibrin affords empyreu-

matic oil, carbonat of ammonia, and very foetid gases, consisting probably of hydrogen, with azot and phosphorus: the remaining charcoal contains phosphat of lime.

Of these three principles, gelatin, albumen, and fibrin, with oxyd of iron and a few neutral salts, principally those having soda and lime for their bases, the blood appears to be formed. It accordingly partakes of all their properties—is coagulated by heat, by alkohol and acids—is rendered thinner by alkalis—has its colour changed by exposure to the several gases—is subject to putrefaction; and when decomposed by heat, affords the mingled products obtained from the separate decompositions of these principles. These products are principally empyreumatic oil, carbonat of ammonia, carbonated and sulphurated hydrogen, and prussic acid; the residual charcoal containing phosphat of soda, phosphat and carbonat of lime, and oxyd of iron.

After stating the composition of the blood, the chemical differences between arterial and venous blood may be considered. This includes the theory

theory of Respiration, the process by which these differences are produced.

The blood, which returns to the heart by the veins from the extremities of the arteries, is of a dark red colour, with a shade of purple. It is transmitted from the heart to the lungs; and during its circulation through them, in which it is exposed to the action of the atmospheric air, it acquires a florid red colour. Being returned to the left side of the heart, it is again circulated by the arteries through the system; and in their extremities it suffers an opposite change, acquiring the dark venous hue.

From these changes of colour it may be inferred, that certain changes in its composition take place; and this is fully established, by the corresponding changes which are found to be produced in the air by respiration. When the air which is expired is examined, it is found to differ in its composition from atmospheric air; it is deprived of the greater part of its oxygen, and it contains a large proportion of carbonic acid, with some aqueous vapour.

It

It may be stated as the mean result of the experiments of different chemists on the extent of these changes in the air, that when 100 parts of oxygen are consumed, 70 parts of carbonic acid are formed. From 30 to 38 cubic inches of oxygen are consumed by an adult in a minute, and from 20 to 26 of carbonic acid are formed; 3 grains of water are expired in the same time.

Experiments on the blood itself have likewise shewn a difference in its composition in the venous and arterial states; in particular, that arterial blood contains a portion of oxygen.

Dr. Crawford advanced the first satisfactory theory to account for those changes which constitute the process of respiration. He supposed, that in the course of the circulation, and especially in the extreme vessels, the arterial blood receives a portion of hydro-carbon, by which it is converted into the venous state; and that in the lungs this hydro-carbon is discharged, and combines in its nascent state with the oxygen of the inspired air, forming the carbonic acid and aqueous vapour, which, with the azot of the atmosphere, are expired.

ed. By losing its hydro-carbon, the blood again becomes arterial.

Lavoisier gave a similar explanation of the phenomena of respiration. He likewise observed, that they might be explained in another mode,—that the oxygen which disappears in respiration may be supposed to be directly absorbed by the blood; that in the course of the circulation it may be combined with carbon or hydro-carbon; and that the carbonic acid thus formed may be conveyed by the venous blood, and be thrown out in the lungs, a new portion of oxygen being absorbed. This explanation was afterwards more fully illustrated by La Grange and Haffenfratz, and is the theory of respiration which is at present, perhaps, most generally received.

Both these hypotheses are liable to objections. The first is deficient in giving no adequate explanation of the conversion of arterial into venous blood, since no source is pointed out whence the hydro-carbon is derived: it does not, when strictly understood, account for the presence of a portion of oxygen, which several facts concur to prove is in venous blood; and it necessarily supposes the
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the aqueous vapour expired to be formed in respiration by the combination of oxygen with hydrogen, while there is every reason to believe that it arises merely from evaporation from the moist surface of the lungs. The second hypothesis is deduced by the most inconclusive reasoning from the facts which have been brought in its support; nor are any of its principles strictly proved. Although it should be admitted that oxygen exists in the arterial blood, it is not proved that this oxygen is in a state of loose combination, or that the whole of the oxygen which disappears in respiration is thus absorbed: the quantity may be merely that which is not spent in the formation of carbonic acid, and which may be necessary for certain purposes in the animal economy. Neither is it proved, that carbonic acid is present in venous blood: its existence in that fluid seems even improbable, since it is found, that carbonic acid added to blood alters its composition in such a manner, that it is incapable of being rendered florid by subsequent exposure to oxygen. And that the carbonic acid discharged is not merely evolved in the lungs, but is immediately formed by the action of the oxygen of the air on the carbon of the blood, appears to be proved by Mr. Davy's experiments, in
which;

which, when hydrogen was inspired for a short time, the production of this acid nearly ceased.

It may be stated, as a more important objection to both these explanations, that the changes they suppose, are not analogous to the usual chemical changes which take place in the animal system; and that they are not sufficiently connected with the purposes which the blood serves in its circulation. When the general facility of combination in the principles of animal matter, and the tendency which the actions of the vessels have to form them into ternary or quaternary principles, are considered, it seems extremely improbable, that oxygen should be absorbed by the blood in the lungs without immediately altering its composition; that without being attracted by any of the other principles of the blood, it should be merely combined with carbon, or with carbon and hydrogen, in the proportions necessary to form carbonic acid and water; and that this carbonic acid, without affecting the ultimate composition of the blood, should be carried the whole length of the venous circulation, and thrown out at the lungs. It is equally improbable, that carbon and hydrogen should be brought into a state
of

of binary combination in the extreme vessels, and should be held merely dissolved by the venous blood, till acted on by the oxygen of the air in respiration.

Still less are the changes which these explanations suppose connected with the changes which the blood suffers. Its principles are expended in the formation of the different secretions, in the nourishment of the solid fibre, and perhaps in the support of the powers of the animal system. But no connection is traced between these known changes, and the supposed communication of hydro-carbon, or the combination of hydro-carbon and oxygen, in the extreme vessels.

The conversion of arterial into venous blood should be considered as intimately connected with, or rather as the result of the changes which are constantly carried on in the extreme vessels, and this conversion, as well as that of venous into arterial blood, must be regarded as arising from changes in the ultimate composition of the known proximate principles of the blood; and not merely from the alternate communication and abstraction of a principle which it holds dissolved in it,

it, or in what is termed a state of loose combination.

According to this view of the subject, the following may be considered as an explanation of these phenomena.

The blood is the source whence all the parts of the body and the products of the system are formed. Its expenditure is constantly supplied by the chyle, a fluid less completely animalised than the blood itself. The peculiar character of animal matter, with respect to composition, is a large proportion of azot, and a diminished proportion of carbon. It may therefore be inferred, that in the extreme vessels, where the animal solids and fluids are formed, the general process will be the separation from the blood of those elements of which animal matter is composed; and that, of course, carbon, which enters more sparingly into their composition, will exist in the remaining blood in an increased proportion. This is accordingly the general nature of *the conversion of arterial into venous blood*. Azot, hydrogen, and other elements, are spent in the formation of new products, and

the proximate principles of the blood remain with an increased proportion of carbon. In this state it is exposed under a very extensive surface to the atmospheric air in the lungs, the oxygen of which abstracts its excess of carbon, and forms the carbonic acid expired. At the same time another change probably takes place, to serve a different important purpose. A supply of oxygen seems to be necessary to support the necessary actions of the system; a quantity of it therefore is absorbed by the blood in the lungs, and expended in the extreme vessels. The combination of these changes, — of the abstraction of carbon by the attraction exerted to it by the oxygen of the inspired air, and the absorption of another portion of oxygen, constitute *the conversion of venous into arterial blood.*

The only difficulty to be obviated in this view of the subject, is that derived from the fact that carbon does not combine with oxygen but at a high temperature, and therefore that no such combination can take place in the lungs. But this is no real difficulty. The carbon is not merely in a state of solution or loose combination; it remains combined with the other elements, and is only in excess in the proximate principles of the venous blood.

blood. And although carbon by itself requires to be raised to a high temperature to combine with oxygen, yet when it makes part of a ternary or quaternary combination, it may be abstracted and combined with oxygen at any natural temperature. This is even exemplified in the blood itself. The experiments of Fontana and others have shewn, that when either arterial or venous blood is agitated with atmospheric air or oxygen gas, carbonic acid is formed, which, with respect to arterial blood at least, must be allowed to be owing to the oxygen abstracting part of its carbon; and if such a combination is possible, it is evident that it must take place more rapidly during respiration, where the circumstances are so much more favourable, where a comparatively high and uniform temperature is kept up, where the blood is exposed over an extensive surface, and in a state of extreme division, and where that surface, as well as the air itself, are rapidly renewed.

From the theory of the changes which the blood suffers in respiration, has been deduced a theory of animal heat, or an explanation of that uniform temperature which animals preserve, in
general

general superior to that of the medium in which they live. It had been observed, that in different animals, the superiority of their temperature to that of the surrounding air, is greater according to the greater size of their lungs; whence it had been inferred, that respiration is the source of animal heat,—a conclusion which Dr. Black confirmed by observing the analogy between this process and combustion, in the changes which are effected in the air,

Dr. Crawford first fully explained this doctrine, and established it by accurate experiments. He had previously shewn, that in general when inflammable bodies combine with oxygen gas, a diminution of capacity takes place, whence there must be an evolution of caloric; and that in the combustion of charcoal, when carbonic acid is formed from the combination of oxygen with carbon, a large quantity of caloric is rendered sensible. It is evident, that since in respiration a similar consumption of oxygen and production of carbonic acid take place, there must be a similar evolution of caloric. He further ascertained by experiment, that the capacity of the blood changes when it passes from arterial to venous; and of course

course from venous to arterial; that of arterial being larger than that of venous blood, in the proportion of 1.030 to 0.892.

On these facts, Dr. Crawford founds his admirable theory of Animal Heat. In respiration, a quantity of oxygen is combined with carbon, or, as he supposes, with hydro-carbon; and carbonic acid is formed. Caloric must be evolved in consequence of this combination. But the blood is at the same time changed from venous to arterial, and by this change acquires a greater capacity for caloric. It therefore takes up the caloric which has been extricated by the combination; so that any rise of temperature in the lungs which would be incompatible with life is prevented. The arterial blood, in its circulation through the extreme vessels, passes to the venous state. In this conversion, its capacity for caloric is diminished, as much as it had been before increased, in the lungs: the caloric, therefore, which had been absorbed is again given out; and this flow and constant evolution of caloric in the extreme vessels over the whole body is the source of its uniform temperature.

Besides

Besides the experiments from which this theory was directly deduced, it has been confirmed by others, in which the quantity of caloric rendered sensible by an animal is measured. Dr. Crawford, and Lavoisier and Laplace, found, that when an animal is confined in a vessel, contrived so as to measure the quantity of caloric which it gives to the surrounding medium in a certain time, and the quantity of oxygen consumed by the animal in that time, this quantity of caloric corresponds nearly to the quantity evolved from the combustion of carbonaceous matter, such as wax or oil, in the same quantity of oxygen.

This explanation is altogether independent on any particular theory of respiration. Whatever may be the nature of the differences between venous and arterial blood, whether the latter contain oxygen or not, or whether the former hold in solution hydro-carbon, carbonic acid, or any other principle,—it is proved by experiment, that the blood in these two states has different capacities for caloric; and on this fact, the explanation of the origin of animal temperature depends. It is likewise the same, whether the combination of oxygen with carbon be supposed to take place in the lungs

lungs or in the course of the circulation ; since from this combination, the carbonic acid expired is derived ; and whenever this takes place, there must be an evolution of caloric.

When an animal is placed in a medium, the temperature of which is considerably high, it still preserves its temperature nearly uniform; the animal heat not rising much above the natural standard. In this case, it has been ascertained by the experiments of Dr. Crawford, that the usual change of arterial into venous blood does not go on, the blood in the veins being nearly as florid as in the arteries. It is evident, therefore, that no evolution of caloric will take place; and it is even possible, that the temperature of the body may be kept low by the blood acquiring an increased capacity for caloric, though other circumstances, particularly the imperfect conducting power of the animal solids, and the increased perspiration, have a share in the effect.

Sect. II. — — OF THE ANIMAL SOLIDS.

THE soft solids seem to be formed immediately of one or other of the proximate principles of the blood.

MEMBRANE, which is the basis of the cellular substance of ligaments, tendons, cartilage, and of the skin, is little else than gelatin. If any of these substances be boiled in water, it is nearly entirely dissolved, and the solution on cooling is gelatinous. The test of tanin likewise shews their identity with gelatin; as when added to their solutions, it forms an insoluble precipitate. The skin, and cellular fibre, are supposed by Seguin to be gelatin rendered concrete by a slight degree of oxydation. The epidermis appears to be still further oxydated; as it is insoluble even in boiling water, though still dissolved by the alkalis and lime. **LIGAMENTS, TENDONS, and CARTILAGES,** have been supposed to contain a greater portion of phosphat of lime, from which they approach to the nature of bony matter. The solutions

tions of some of these substances, obtained by strong boiling, are employed as nutritious articles of diet, or in the arts, on account of their adhesive quality, as glue.

BONE contains a large proportion of gelatin, and seems to consist principally of that matter united with phosphat of lime. By boiling under an increased pressure, the gelatin is dissolved. By maceration in an acid, the greater part of the phosphat of lime is extracted, and a soft membranous matter, having the figure of the bone, remains. When bones are decomposed by heat, the products are carbonat of ammonia, a foetid empyreumatic oil, and carbonated hydrogen: the residuum is principally phosphat of lime, with smaller quantities of carbonat and sulphat of lime. HORN is similar in its composition and properties to bone. The substance of shells contains a much larger proportion of carbonat of lime: in some animals, it consists almost entirely of it.

MUSCULAR FIBRE seems to have fibrin for its base. When washed with water, it is white, insipid, and elastic; and when treated with nitric acid,

gives out azotic gas, and is converted into oxalic and malic acids. The water in which it has been macerated contains, besides the colouring matter of the blood, gelatin and albumen, with a small proportion of saline matter and of fat. In young animals, the gelatin is more abundant in the muscular fibre than in old, in whom the fibrin rather predominates. When muscular fibre is decomposed by heat, besides the usual products of animal matter, a peculiar acid, the Zoonic, is obtained.

FAT appears to be a peculiar secreted matter, as no traces of it can be discovered in the blood. It is contained in minute cells, and is nearly fluid, but becomes harder when extracted from the body. Its properties are nearly the same as those of vegetable expressed oil. It is insipid and inodorous, insoluble in water and in alcohol, inflammable, and capable of combining with alkalis so as to form soap. It becomes rancid on exposure to the air, owing, it is supposed, to the absorption of oxygen, and the consequent formation of a peculiar acid. It is also capable of being oxydated by the acids, especially by the nitric.

Fat

Fat is decomposed by heat : an acid liquor, a considerable portion of an acrid empyreumatic oil, and carbonated hydrogen, are disengaged, the residuum being charcoal. The acid liquor thus obtained has been ~~supposed~~ to be a peculiar acid, and has been named the Sebacic. When obtained pure, it is fluid and colourless, has a pungent odour, and a sharp acid taste : it reddens the vegetable colours, and combines with the alkalis, the earths, and several of the metallic oxyds. It is decomposed by heat, carbonic acid being disengaged, and charcoal remaining.

Fat is capable of combining with metallic oxyds ; and from its facility of oxydation, it can be made to act upon several of the metals. It thus converts copper into a green oxyd, and facilitates the oxydation of mercury by trituration,

The solid matter of the brain has been analysed by Fourcroy. The pulpy matter of which it chiefly consists, approaches most nearly in its properties to albumen. It is mixed with several saline substances, particularly with phosphats of lime, ammonia, and soda.

SECT. III. — — — ANIMAL FLUIDS.

ANIMAL Fluids are chiefly the products of secretion. The principal of them are, Milk, Lymph, Mucus, Saliva, the Gastric Liquor, Bile, Urine, and Perspirable Matter.

MILK.—This fluid, designed for the nourishment of young animals, is secreted by the glands, situated in the breast of the female. It is white, opaque, inodorous, and sweet; varying, however, in its sensible qualities, as obtained from different animals.

When milk is allowed to remain at rest for some time, a white fluid, of a thick consistence, collects at the surface. This cream is of an oily nature, and when agitated for some time separates into a fluid and a solid part; the latter being a concrete oil, or butter, similar in its properties and composition to animal fat.

After

After the spontaneous separation of the cream, the milk continues to suffer other changes. It first becomes aced, and then coagulates: when the fluid is pressed out from the coagulum, a dry matter, somewhat elastic and insoluble in water, is obtained. This is the Cheese, or Caseous part of milk. Its separation appears to be owing to the formation of an acid in the milk, since it can be at once separated by the addition even of any of the weak acids: it is also separated by alcohol, and various other substances; and likewise by heating the milk, the thin pellicles, when they form on its surface, being the caseous matter. The liquor found in the stomach of young animals, or the infusion of the membrane of the stomach itself, separates the cheese most completely, and is used where it is prepared as an article of food.

The caseous matter of milk is a white or greyish matter, somewhat elastic, when fresh nearly insipid, insoluble in cold water, soluble in the alkaline solutions, with slight decomposition, a smell of ammonia being disengaged, and likewise partially soluble in the diluted mineral acids. Exposed to the air in a moist state, it soon putrefies. Decomposed by heat, it affords an empyreumatic oil,
ammonia,

ammonia, and carbonated hydrogen, the residuum being charcoal, which, when burnt, affords fixed alkali.

When these two principles, the butter and the cheese, have been separated from the milk, there remains a liquor, termed the Serum, or Whey, of a yellowish colour and slight tenacity, and of a bland agreeable taste : when evaporated, it affords a substance of a saline appearance. This, by a second solution and evaporation, may be obtained in rhomboidal crystals, of a white colour and sweetish taste. It is termed the Sugar of Milk. It is soluble in 7 parts of cold, and 4 of boiling water,

When the sugar of milk is treated with nitric acid, assisted by a moderate heat, nitrous gas is discharged ; the solution becomes yellow ; and as it advances, a copious deposition of a white matter takes place. The fluid contains oxalic acid ; the white concrete possesses the properties of an acid : it is soluble in water, though very sparingly ; it is more soluble in alcohol ; and it combines with the alkalis and earths, forming peculiar salts. It is termed the Saccho-Lactic Acid. Scheele, who discovered

discovered it, concluded, that it is not formed in the process by which it is obtained, but that the sugar of milk is a compound of it with saccharine matter; and that this latter matter being oxydated by the nitric acid, the former is separated. This opinion is adopted by Parmentier and Deyeux, by whom milk has been fully analysed,

From the quantity of saccharine matter which the milk contains, the whey is susceptible both of the vinous and acetous fermentation. The latter is not entirely similar to the acetous fermentation of vegetable matter; the presence of the air is not necessary, and the acid which is formed is different from vinegar. It cannot be distilled without suffering decomposition, and it forms peculiar salts with the alkalis and earths. It is termed the Lactic Acid, and is much more soluble than the saccho-lactic. It cannot be crystallized.

Besides the sugar of milk, there are some other saline substances present in the serum, principally murats of lime, potash, and soda, with some salt containing phosphoric acid.

LYMPH

LYMPH.—The fluid contained in the lymphatic vessels is pellucid, insipid, and slightly viscid ; it seems to be merely a solution of the albumen, and gelatin of the blood.

MUCUS, or that thickish fluid which covers the surface of the different passages and cavities of the body, appears to be little else than inspissated lymph ; it is thicker, more viscid, and of a greater specific gravity.

SALIVA is a fluid secreted by the glands in the mouth, designed to facilitate the mastication of the food. It is nearly tasteless ; is imperfectly soluble in water ; is coagulated by alcohol and the mineral acids ; and is dissolved by the alkalis, emitting, during the solution, a smell of ammonia. It appears to consist of albumen dissolved in water with a portion of muriat of soda, and, as some have affirmed, of phosphat of lime.

The **GASTRIC FLUID**, or liquor secreted in the stomach, is limpid, has a slightly saline taste, and is soluble in water. It is not of an acid nature, as some have imagined, though it is often mixed with an acid liquor present in the stomach,
from

from some morbid affection. It is not coagulated by acids or alkalis, and is so very slightly by alkalis.

The most remarkable property of this fluid is its solvent power with respect to the food. This belongs in an eminent degree to the gastric juice of carnivorous animals, animal matter being dissolved by it with facility. In animals which feed on vegetables, it is much less remarkable, though it is still to be observed. In the one, digestion is performed principally by solution; in the other, the strong muscular contraction serves to triturate the food; and thus facilitates its subsequent solution.

The chemical composition of this fluid has not been ascertained. When exposed to heat, it affords a large quantity of water, and the dry mass obtained by complete evaporation affords ammonia and an empyreumatic oil; a mass remains, which contains carbon with muriat of soda and some other neutral salts.

BILE is a fluid secreted by the liver from the venous blood. It enters the intestinal canal, and,

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from the large quantity secreted, appears to serve an important purpose in the assimilation of the food. It is of a thickish consistence ; its colour is green, with a deep shade of yellow ; its taste is intensely bitter ; its odour faint. It is soluble in water.

When bile is evaporated by a moderate heat, a tenacious mass is obtained : if this be exposed to a stronger heat, an empyreumatic oil, carbonat of ammonia, prussic acid, carbonic acid, and carbonated hydrogen, are produced. The residuum is charcoal, which, when burnt, is found to contain muriat and carbonat of soda, and phosphat of lime.

Bile is coagulated by alcohol, and this coagulation serves to discover its proximate principles. If the coagulum is separated by filtration from the green fluid in which it floats, a white viscid substance is obtained, nearly tasteless, and possessing the general properties of albumen. The filtered liquor retains the green colour and bitter taste of the bile. If the alcohol be evaporated, a concrete matter is obtained, inflammable, fusible at 120° , soluble in alcohol, and precipitated from
this

this solution by water. As this substance has the general properties of resinous matter, it is termed the Resin of the Bile. It is likewise separated, but imperfectly, from the bile by acids. By the oxygenated muriatic acid it is converted into a white concrete substance, of an unctuous appearance, which still retains its bitterness, and is soluble in alkohol, and in water assisted by heat.

Besides these principles, bile contains soda, apparently combined with carbonic acid: this gives it a saponaceous quality.

There are frequently formed in the gall bladder, concretions termed Biliary Calculi. These vary in their colour, texture, and hardness. Frequently they consist, entirely or chiefly, of crystalline laminae, easily separable from each other; of an unctuous appearance, and inflammable. Some are soluble in alkohol, and in essential oils; others are not. Besides the particular crystalline matter which enters into the composition of many of these calculi, analysis has detected in them a resinous matter similar to that of the bile, a quantity of acid of benzoin, and minute portions of lime, soda, and ammoniacal salts.

URINE.

URINE.— This fluid, secreted by the kidneys, and discharged by the bladder, is excrementitious, or is designed to convey from the body what, if retained, might prove injurious. When newly discharged, it is transparent; its colour pale yellow; its smell peculiar; its taste saline and nauseous. When immediately examined, it is found in general to be slightly acid; but in a short time a quantity of ammonia is evolved, which renders it alkaline. As it becomes cold, its transparency is diminished, from the addition of saline matter, which the animal temperature had enabled it to retain dissolved.

When urine is exposed to a moderate heat, its watery part is evaporated along with carbonat of ammonia. A thick mass is obtained, of a brown colour, and very foetid smell: this, when urged by heat, affords very fœtid empyreumatic oil, carbonat of ammonia, several compound gases, and a small portion of phosphorus.

Urine kept either in close vessels or exposed to the air soon undergoes putrefaction, and a large quantity of ammonia, of a very foetid smell, is disengaged.

The

The fixed alkalis added to urine throw down a slight precipitate, which is phosphat of lime. — Lime water produces a copious precipitate of a similar kind. The infusion of tannin detects in it a greater or less proportion of gelatin. The acids do not produce any remarkable effect upon it. Muriat of barytes causes a precipitate, by decomposing the phosphoric salts. The nitrats of mercury, lead, and silver, likewise occasion a copious precipitate, arising from the combination of the metallic ~~acid with tartaric~~ and phosphoric acids.

When by these tests, or evaporation and crystallization, the saline matter contained in urine is examined, it is found to consist of a variety of salts. The principal are the phosphats of soda, ammonia, lime, and magnesia, — muriats of soda and ammonia, — lithic or uric acid, — and sometimes, especially in the urine of children and granivorous animals, acid of benzoïn.

Of these, the Lithic acid is the only one that has not been examined. It forms the principal part of the red-coloured precipitate which urine deposits. When pure, it is concrete, and of a crystalline form; is very sparingly soluble in water.

ter. Its solution reddens the vegetable colours. It combines with the alkalis and earths, though to either of them its attraction is inferior even to that of carbonic acid: hence it is not soluble in the alkaline carbonats. Nitric acid decomposes it, communicating to it a portion of oxygen, and forming a substance of a red colour,

Besides the saline substances existing in urine, and the gelatin and albumen it occasionally contains, there exists in it a large quantity of a peculiar matter, in which the colour, odour, and principal properties of the urine reside. This substance has been named *Urée* by Fourcroy and Vauquelin, by whom it has been more particularly examined.

They obtained this principle by evaporating urine to the consistence of honey, and adding alcohol, which dissolves the *urée*, with small quantities of muriats of soda and ammonia. The alcohol is evaporated; the residuum is diluted with water to the consistence of a syrup, and nitric acid is added: this combines with the *urée*, forming a compound soluble in water. Potash is added to its solution, which combines with the nitric acid: the

the liquor is again evaporated; alcohol is added, which dissolves the urée, and by evaporation affords it pure.

Urée dissolved in water gives it the colour, smell, and other properties of urine. It is very susceptible of decomposition, and forms carbonat of ammonia, by its elements entering into new combinations. By heat it is almost entirely converted into carbonat of ammonia, a small quantity of oil only being produced. It is supposed to constitute about the twentieth part of urine.

From a knowledge of the composition of urine is to be derived that of Urinary Calculi, a subject of much importance in a medical point of view.

Scheele discovered that these concretions consist principally of the lithic acid; that this acid could be obtained from them by solution in an alkali, and precipitation by an acid. It exists in them combined with animal matter, apparently albumen. Bergman could discover not more lime in a calculus than the 200th part of its weight. Other chemists have occasionally found a much larger proportion of phosphat of lime. The distinguishing

tinguishing character of the calculi consisting of lithic acid, is their solubility in the pure alkalis.

Besides these, calculi are sometimes found insoluble in the alkalis, and which must therefore be of a different nature. Fourcroy and Vauquelin have analysed several of this kind. They found some composed principally of the lithic acid with ammonia; others, of a triple salt, consisting of phosphoric acid with ammonia and magnesia;— and in a third variety, named the Mulberry Calculus, from its dark colour and rough surface, they found oxalat of lime. In all these, animal matter likewise existed.

PERSPIRABLE MATTER.—From the surface of the body there is a constant exhalation, partly of a permanent gas, and partly of an aqueous fluid. The latter, when copiously secreted, forms the Sweat. It seems to be principally water, with a portion of saline matter, and of some animal substance, probably lymph. The former is carbonic acid: it is discharged in very inconsiderable quantity.

CHAP. III.

OF THE

DECOMPOSITION OF ANIMAL MATTER.

ANIMAL Matter may be decomposed by heat, by the action of other chemical agents, or by the reaction of its principles, constituting the process of Putrefaction.

When animal substances are exposed to heat in close vessels, the usual products are, an empyreumatic oil, ammonia, carbonic acid, and different compound gases containing azot, carbon, and hydrogen, and sometimes also sulphur and phosphorus. From some substances two peculiar acids, the Pruffic and Zoonic, are likewise produced. The residuum is a charcoal difficult of incineration, and containing oxyd of iron and various neutral salts, particularly those formed by the phosphoric

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and muriatic acids. Of these products it is necessary to notice only the Prussic and Zoomic acids.

PRUSSIC ACID derives its name from the pigment termed Prussian Blue, of which it forms a component part. This substance is prepared by calcining with a moderate heat three parts of dried blood, and two parts of coarse potashes.— From the calcined mass, a ley is obtained by dissolving it in water. This is mixed with a solution of one part of sulphat of iron; and two parts of alum : a green precipitate is formed, which, when washed with diluted muriatic acid, assumes a beautiful blue colour, and forms Prussian Blue.

Macquer discovered, that this substance is a compound of oxyd of iron, and a peculiar principle, which can be abstracted from the oxyd by boiling the Prussian blue with an alkali. Scheele proved, that this principle is an acid, capable of combining with the alkalis, earths, and metallic oxyds, and forming salts, some of which are crystallizable, others deliquescent. These are termed Prussiate.

It is extremely difficult to obtain this acid entirely

tirely pure, a small portion of oxyd of iron remaining combined with it, in the usual processes by which it is obtained. It is obtained nearly pure by decomposing the prussiat of Potash by sulphuric acid with the application of heat, and receiving the Prussic acid, which distils over, in water, or in a solution of pure potash.

In the formation of Prussic acid by the decomposition of blood or other animal substances by heat, ~~part of the carbon~~, hydrogen, and azot, of the animal matter, with a small portion of oxygen, combine together. It can likewise be formed by another process, in which these elements are combined—by bringing ammoniacal gas in contact with charcoal heated to redness. When decomposed by heat it is resolved into carbonated hydrogen and carbonat of ammonia; the residuum containing, it is affirmed, a small portion of phosphoric acid. Berthollet had supposed, that this acid contains no oxygen; but Vauquelin remarks, that however dry an alkaline prussiat may be, its analysis always affords carbonat of ammonia; and that in the formation of it from ammonia and charcoal, the quantity of it is much increased by the addition of any substance capable of affording oxygen.

Pure

Pure Prussic acid has an odour somewhat fragrant, and a sweetish taste: it is volatile, and inflammable; is soluble in water; its solution does not redden the vegetable colours: it is decomposed by the nitric and oxygenated muriatic acids, which communicate to it oxygen.

Of the salts which this acid forms, it is only necessary to notice that with oxyd of iron,—Prussian Blue. Proust has shewn that this compound is afforded only by the iron highly oxydated, and that with the imperfect oxyd the Prussic acid forms a white precipitate. The formation of Prussian blue is a case of double elective attraction; prussiat of potash and sulphat of iron being mixed together, and the Prussic acid uniting with the oxyd of iron. An excess of oxyd of iron is thrown down, which gives a green colour to the precipitate; this is dissolved by washing it with diluted muriatic acid. The alum which is added in the preparation is likewise decomposed, and affords argillaceous earth. This mixes with the precipitate, increases its quantity, and by giving it a degree of consistence, renders it even more convenient for use.

ZOONIC ACID, lately discovered by Berthollet, exists combined with ammonia in the fluid obtained from animal substances by destructive distillation. From this combination it may be obtained by adding lime, which attracts the zoonic acid; and decomposing the zoonat of lime, by heating it with phosphoric acid, the zoonic acid distilling over. It has likewise been obtained from the gluten of wheat, and from the yeast produced in the fermentation of beer.

This acid has a peculiar smell, and a styptic taste; it reddens the vegetable colours, and excites effervescence with the alkaline carbonats. Its salts are not crystallizable.

OF the decompositions of animal matter by chemical agents, the principal are that by the fixed alkalis, and that by the nitric acid. The former generally dissolve animal matter, and at the same time cause part of their hydrogen to combine to form ammonia, while a portion of carbon seems likewise to be precipitated. Nitric acid causes a disengagement of azot from animal substances, and brings their remaining carbon, hydrogen,

gen, and oxygen, to combine so as to form oxalic and malic acids: sometimes also it forms Prussic acid. The largest quantity of azot is disengaged by it from fibrin, the next from albumen, and the least from gelatin.

THE spontaneous changes which animal matter undergoes from the re-action of its elements, are various, according to the circumstances under which it is placed.

If it be completely excluded from air and moisture, it decays with extreme slowness; it is finally changed, however, so that nothing remains but an earthy-like substance,

If those animal substances which are not soluble in water, those, for instance, which consist principally of fibrin, as the muscular fibre or flesh, be kept immersed in water, the soluble parts are removed; and the fibrin is changed into a fatty matter, similar to spermaceti. A similar change is produced by the agency of very diluted nitric acid on the muscular fibre. In either case the azot and phosphorus seem to be disengaged, probably

bably in combination with hydrogen ; while another portion of the hydrogen, with perhaps a quantity of oxygen, remain combined with the carbon, and form the fat.

When atmospheric air is not entirely excluded, and when moisture, with a certain degree of heat, is present, the process termed Putrefaction commences. The elements of the animal matter enter into new combinations, which generally pass off in the gaseous form ; and an inconsiderable quantity of earthy matter remains when the process is finished. The precise nature of these combinations has not, from the extreme offensiveness of the process, been accurately observed ; and they probably vary according to the nature of the animal matter, and the circumstances under which it is decomposed. Ammonia formed by the union of the azot and hydrogen of the animal matter, is always disengaged in considerable quantity. Phosphorated hydrogen is likewise produced, as this gas, even when obtained pure, has the odour exclusively termed putrid, and as putrefaction has been often observed to be accompanied with the extrication of a luminous gas. Sulphurated hydrogen forms another part of the vapours disengaged

gaged from putrefying substances, as these vapours have in some degree its smell, and blacken the metals,—a peculiar property of this gas. Carbonated hydrogen and carbonic acid are likewise separated. And lastly ; It is probable that not only these binary combinations, but compound gases consisting of three or more of these elements with oxygen, are formed and discharged,

As this process must necessarily be carried on at the surface of the earth, its products are diffused through the atmosphere, dissolved by water, and absorbed by the soil. They furnish the principal nutritious matter for the support of vegetables, and are again prepared for the nourishment of animals.

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